California Soils

BAILEY

Introduction
TO THE
SOILS of CALIFORNIA

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FOREWORD

A preface should not be an apology for spreading printers' ink on paper. It should be a statement of the author's purpose; something to give the work more force, and enable it to do the good it was planned to do; something to place the reader in closer touch mentally with the writer.

The soil is the principal asset of the nation. It provides the raw material for upward of sixty per cent of the gross value of all the products of manufacture, and the railroads and steamers with a large part of their tonnage. It supplies the population of the country with most of their food and clothing, with much of the material for their houses and house furnishing, and with part of their fuel. In spite of these facts this "the greatest of assets" is neglected, abused and misunderstood. This slight superficial and inconstant covering of the earth should receive a measure of care which is rarely devoted to it. Every owner of land needs to know something of the part of the earth he is dealing with or in. The soil is a precious inheritance that should be jealously guarded and protected instead of being abused and neglected. It is abused mainly through ignorance rather than intention, and one object of the author is to help a little in removing some of this ignorance. The soil must be understood. One needs at least some definite knowledge of its physical and chemical character, its hygiene, productive capacity, and adaptability to crops.

Too many look upon the soil as something essentially unclean, in which seeds manage in some mysterious way to grow. This attitude should be changed to admiration of the beauty, harmony, and order of the mechanism of the soils, on which the existence of all living beings depend; to the vast array of forces involved; to the perfect order of their action; and to the design, purpose and intention shown in their construction. Long familiarity has placed over the soil the veil of the commonplace and hidden the dignified meaning that exists in its structure. Men look at the soil without seeing, and walk over it without thinking. They forget that the solid and substantial wealth of our nation comes from the

country and not from the city, and that this hard-earned wealth should be used largely to improve the country and its institutions. We must never in any of our philosophies get away from the land. One object of the author is to show that the commercial value and relation to crops can be seen in the field from the physical character of the soil.

The grouping by classes, such as the loams, sandy loams, silt loams, etc., brings out best the uses to which the soils are adapted, and calls attention to the similarity of soils and to the possibilities of the extension of industries into new localities, climate and economic conditions permitting. The time has passed for trying to plant round pegs in square holes; for using a thousand acres of citrus land for raising two hundred pigs; for using lima bean and sugar beet land for Texas steers; or for raising chickens and Belgian hares on choice date land. The cry of common sense is "intensive farming," "a little land well tilled, and an ample purse well filled."

The new agriculture is advancing on the Pacific Coast with strides that attract the attention of the world, and one object of this work is to make accessible information that is scattered through a great number of government and individual reports that are not accessible to most people, and to arouse an interest that will lead the tillers of the soil to study and investigate for themselves, and to point out the way.

The soil and its problems offer a field of study of the highest importance not only to the development of the welfare of the human race, but to obtaining personal financial returns. This introduction to our soils is an attempt to place in readable form some of the results of scientific thought and discovery, and to prove that a minute study of the soil is worth while. The educational value of any book or subject lies not so much in the actual information presented as in its arrangement into systematic treatment so as to develop a philosophy of the subject. Schools will not make farmers or housekeepers but they can stimulate an interest in youth in the problems connected with these two important vocations and develop clear thinking, sound argument, constructive imagination and effective application.

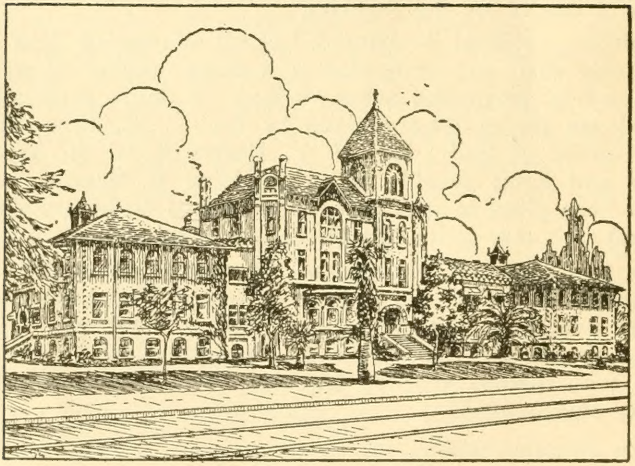
The attempt has been made to be practical rather than

scholarly, direct and simple instead of technical, and of service to every man who owns an acre or is getting a living from the soil rather than for the class room or library. An effort has been made to avoid unnecessary technical words and terms so far as this can be done without dodging or shying at unfamiliar words necessary to embody new ideas. The independent farmer wants to know the whys and wherefores, and he wants a simple statement of observed fact and the most positive proof of the correctness of such statement; therefore, only the facts have been compiled, and the reader referred to special works for the theories.

Nothing original is claimed, but all sources of data have been freely used and obligation to a large number of authorities is hereby given and acknowledged. I desire especially to acknowledge the assistance given by Mr. E. E. Free, of the U. S. Bureau of Soils; Mr. M. V. Hartranft, of the Western Empire and Fruit World; and Hon. Wm. E. Smythe, whose life has been given to making each individual do his duty to an acre, and each acre do its duty to the individual and to the world.

As to mistakes, if you point them out they will be corrected *next time;* but the farmer or writer who hesitates for fear of mistakes will never accomplish anything. As to critics,—remember the words of the scientist: "Animated beings who inhabit vitrified tenements ought not to project lapidary fragments."

Los Angeles, 1913.



UNIVERSITY OF SOUTHERN CALIFORNIA
LOS ANGELES

PART I

CHAPTER I

AGRICULTURAL GEOLOGY

THE SOIL is the one indestructible, immutable asset that our nation possesses. It is the one resource that cannot be exhausted, that cannot be used up, but if properly cared for, not only clothes and feeds us but improves with age and proper treatment for the continued use of posterity.

It forms the basis of our industrial wealth and a large portion of our foreign exports, yet we are taking up the last of our public lands while the country is so sparsely settled that less than one-fourth of the land nominally in farms is actually under cultivation. From these lands we obtain from only one-third to one-half the yield per acre obtained on the older soils of Europe.

It is dependent upon us to study the soil, to understand its origin, composition, properties, functions, and relations to crops, to understand the changes brought about by cultivation and cropping, to win from the soil not only for our present needs, but to increase the yields for the larger population that follows.

The problems are many and some are complex. The weight of an acre of soil one foot deep is about 2000 tons. The art of soil management is to so manipulate and handle this 4,000,000 pounds of raw material at a cost of ten or twelve dollars an acre as to produce the greatest quantity of profits, and still leave the soil unimpaired for future generations.

The more a man knows of the nature of the soil the better prepared he is to handle it properly.

AGRICULTURAL GEOLOGY. Since all soil materials form a part of the structure of the earth, their origin, character, and classification constitute a part of the field of geology. *Agricultural geology* is a history of the outer mantle of the earth, its materials, origin, character, uses and value.

The soils of California come from a great variety of geologic formations. Almost the entire geologic column from the Cambrian to the latest Quaternary is represented. The rocks of each

of these formations has weathered into soil somewhere in the state, giving the student exceptional opportunities for study. Over 200 soil types have so far been recognized by the United States Department of Agriculture and mapped in California. The crops produced range from the wheat, corn and barley of the colder climates to the rice and cotton of the South; from apples, peaches, and pears to oranges and lemons; from hops to wine and raisin grapes; from pine forests to date palms; from blackberries to alligator pears. The soils themselves range from those at the feet of living glaciers to those in the midst of deserts; from meadows 12,000 feet above sea level to burning sands below sea level. No other state in the Union presents such a variety of soils or of products, or offers such an opportunity for investtigation.

THE EARTH is one of the organisms of the Universe in which all parts work together harmoniously according to plan, intention, and design, as much as those of an animal or plant. It was born, will reach maturity, pass through old age, and finally die (that is, change form) only to renew its existence in another form. The earth is not therefore in any of its parts to be considered as a dead, inanimate thing, but like a tree it is most active on the outside. The mantle of the earth, or soil, is not a changeless, lifeless, inanimate thing, but is ever moving and changing, and teems with life and activity .

The relation of the earth to the sun determines the amount of heat the soil receives, and gives us the *seasons*. The forms of the earth's surface determine the angle at which the parallel rays of the sun strike the different portions of the mountains, hillsides and plains, and the amount of heat per square mile, giving temperatures that range from frigid to torrid. The inclination of the earth axis combined with its daily and yearly motions determines the seasons at the various latitudes. The annual revolution around the sun gives a succession of seasons, warm, cold, wet or dry, establishing the *principle of rotation*, or alternating periods of rest and activity for the soils. The daily rotation of the earth on its axis gives alternations of light and darkness, heat and cold; giving soils, plants and animals short and frequent periods of activity and rest. The structure of the earth, like the structure of a plant or animal, includes solids, liquids and gases.

THE SUN, as large as 300,000 earths, furnishes by wireless

the light, heat, chemical and electrical rays which keep things moving and active upon the surface of the earth. It is clearly these forces from the sun that cause all the movements of animal and vegetable life, and all the growths of roots and stems, the germination of seed, the opening of the bud, and the ripening of the fruit.

THE ATMOSPHERE is an intimate mixture of all substances that cannot take a liquid or solid state at the temperatures and pressures that prevail at the earth's surface. It contains 79 parts of nitrogen, 21 parts of oxygen, .03 parts of carbonic dioxide, and small quantities of argon and other rare elements. The water vapor contents vary from time to time and from place to place, as do the gases that come from volcanoes, cities and manufactories, and a great variety of volatile organic substances. Dust and other forms of solid matter are often suspended in the atmosphere as impurities. It is mobile and active and has great direct and indirect effect upon water, rocks and soils. It is a thermal blanket distributing and equalizing temperatures, and sustaining and promoting life.

THE HYDROSPHERE. The water which lies upon the surface of the earth would form a universal ocean a little less than two miles deep if the earth was a perfectly smooth sphere. It occupies 72 per cent of the earth's surface and is apparently the greatest of all geologic agents, constantly changing the forms of land surfaces and the temperature. It is destructive and constructive, ever tearing down and building up. The historical records of geology are largely due to the fact that the waters have buried in systematic order relics of the life of successive ages past.

THE LITHOSPHERE. The ground upon which we stand is a part of the outer crust of the *lithosphere* or *rock sphere* of the earth. It is composed of loose, incoherent material commonly called earth or soil, and consists of clay, sand, gravel, pebbles, and boulders, or mixtures of these. The great lithosphere or rock globe is an oblate spheroid with a polar diameter of 7,899 miles and an equatorial diameter 26.8 miles more. Its surface area is 196,040,700 square miles, of which only 55,153,500 square miles are land, and only a small portion of this is soil capable of cultivation and supporting human life.

The atmosphere and hydrosphere are mantles rather than

true spheres, and both penetrate the lithosphere to some extent. In order to understand the origin of soils, their properties and value, one must know the character of the lithosphere and the action of the atmosphere and hydrosphere upon it.

THE FACTORS. The character of the soil of any region depends upon two great groups of factors: (1) The character of the *material* from which is has been derived; (2) the *processes* by means of which this material has been converted into a soil capable of supporting plant growth.

The first has to do with *soil-forming materials* which are part of the lithosphere, and the second with *soil-forming processes* which are largely the action and reaction of the atmosphere and hydrosphere upon the lithosphere.

The two factors are intimately associated, and any given soil is always the resultant of a definite combination of these soil-forming factors. *Uniformity in the factors* gives *uniformity in the soils*, giving definite soil types; while any variation in the factors gives a change in character amounting to a phase or subtype of soil. A knowledge of these factors is therefore essential to a proper understanding of the soils of any region.

CHAPTER II

SOIL FORMING MATERIALS

ROCKS. The rocks at the surface of the earth are all fragments of still older rocks of former geologic periods, broken up and more or less decomposed, and form a sheet of loose fragmentary material that is called *mantle rock* because it overlies and covers the compact, coherent mass below that cannot be easily broken up or removed and is known as *bedrock*.

Where the bedrock projects through the soil, as on a hillside or along the banks of a creek, it is called an *outcrop*. If the bedrock lies in distinct sheets or layers, called *strata,* it is said to be *stratified.*

The common kinds of stratified rocks like shale, sandstone, and limestone, are also called *aqueous* or *sedimentary* rocks because they were formed in water on ocean bottoms, or lakes, as sediments that in time became hardened (*indurated*) into rock. A rock may contain material of one kind only, as limestone, or it may contain material of several kinds as in the case of granite. It may be loose or *unconsolidated* like sand, or it may be solid (*consolidated*) like sandstone.

It is desirable to know not only the kind of rocks from which the soil is formed but also in what physical form these compounds exist. Examine a rock with a magnifying glass, or place thin sections under a microscope, and it is seen that all rocks are composed of particles of different sizes and shapes and kind, which are sometimes held together weakly and sometimes firmly. These particles are called *minerals;* for example, we say that the rock granite is composed of the minerals mica, quartz, and feldspar.

Rocks are classified according to their chief mineral constituent. Rocks composed largely of lime are said to be *calcareous;* of quartz, *siliceous;* of iron, *ferruginous;* and of clay, *argillaceous.* If eruptive rocks contain over 60 per cent of silica (quartz), they are said to be acidic; if less than 50 per cent of silica, they are spoken of as *basic.* Rocks are often named according to their structure as *crystalline,* such as granite and marble; *vitreous* or glassy, as obsidian and other volcanic rocks;

collodial or amorphous in structure, as siliceous sinters and flint nodules; or as *fragmental* when composed wholly of the fragments of pre-existing rocks held together by clays or cementing material. Where rocks have been forced up through fissures penetrating other rocks, they are said to be *intrusive*. Rocks formed by heat, as the lavas, are called *igneous*. If igneous or sedimentary rocks have been radically altered in appearance or character, especially one that has been rendered crystalline by heat or pressure, it is called *metamorphic*.

Adobe is classified as a rock when considering the thick clayey accumulations in the basins and plains of the arid region. It is a fine clayey or silty deposit formed by the gentle wash from slopes that lodges on the flats below. *Clay*, considered as a rock, is a term commonly applied to any soft, unctuous, adhesive deposits composed largely of aluminum silicates. Many so-called clays are chiefly siliceous silts or loams and not true clays. Note the definition of clay in soil anaylsis. *Conglomerate*, often called puddingstone, is a rock composed of rounded pebbles, or of unconsolidated gravel. *Drift*, in common American usage, is a mixture of clay, sand, gravel and boulders formed by the action of glacial agencies. *Eolian* rocks are deposits formed by wind, embracing especially sand dunes and much of the loess. *Gneiss*, a foliated granite and often called stratified granite, consists normally of quartz, mica, and feldspar. *Granite* is a granular crystalline aggregate of quartz, mica, and feldspar. It is popularly, and properly, used for any distinctly granular and crystalline rock. Granite and gneiss crumble first into barren gravel, then the quartz crumbles into sand, and the mica and feldspars decay into clays. *Greenstone* is a comprehensive term used to designate igneous and metamorphic crystalline rocks of greenish hue and of intricate and minute crystallization. It is a convenient field term where the mineral constituents cannot be readily determined. They are usually, in California, dolerites, diabases, or diorites. *Igneous*, or fire-formed rocks, differ widely in composition and texture, and therefore weather into a great variety of soils, some of which are poor, and some of which are exceptionally fertile. *Lava* is a molten rock of variable composition coming from vents or fissures and solidifying at the surface. They vary in fertility according to their composition. *Limestone* is a rock composed primarily of calcium carbonate, but is called *dolomite* if it also contain considerable carbonate of magnesia.

Marble is pure crystallized limestone, or metamorphozed limestone. *Loess* is a very fine porous siliceous silt containing some calcium material which often collects in nodules. It is characterized by its standing in vertical walls and weathering so slowly that letters cut into it remain distinct for years. Its origin is still a matter of controversy among geologists, being held by some as purely eolian, by others as fluvial (stream) or lacustrine (lake) formation, and by many more as partially eolian and partially aqueous. *Mantle rock* or *regolith* is the earthy mantle that covers the indurated rocks, and consists chiefly of residuary earths, soil, and subsoil. *Marl* is an earth formed largely of calcium carbonate, usually derived from the disintegration of shells, or from the calcareous secretions of plants. The term is also applied to glauconitic and other fertilizing earths. *Ooze* is a soft deposit of the deep seas, and is characterized mainly by shells of microscopic size. *Sandstone,* or indurated sand, consists of grains of quartz, or grains of the various hard silicates. *Quartzite* is metamorphosed or crystalline sandstone generally. *Shale* is a more or less laminated rock consisting of indurated muds, silts, or clays. They are often the hardened soils of former geologic times that weather into silts and clays and make good soils if not too compact. *Slate* is a clay rock finely laminated and fissile, and can be split into thin sheets like common roofing slate. It is apt to weather into clay soils that are heavy and compact. *Till* is a stony or bouldery clay, or rock rubbish formed by glacial action. *Tuff,* or *tufa,* embraces the ashes, cinders, etc., of volcanic eruptions. Calcareous tufas embrace also the granular and cellular deposits of springs, such as those of the Mono Lake district.

MINERALS. Of all the hundreds of minerals named and classified, less than fifty are important geologically or commercially, and only about a dozen of them are used in forming the common rocks from which the soils are derived. *Quartz* is familiar to all as the chief constituent of sand. It is composed of 46.7 per cent of silicon and 53.5 of oxygen. It occurs in most rocks as grains without definite shape. It will scratch glass and cannot be scratched by a knife. When rocks decompose, the minerals are broken up and the elements enter into new combinations, but the quartz remains unaltered and is washed away or blown away, forming sand, sandstones, siliceous rocks, quartzites and cherts. It is an ingredient of all soils, giving them lightness,

drainage, and promoting aeration. *Feldspars*—There are several kinds of feldspars, composed of silica and aluminum, together with potassium, calcium, and sodium. In the orthoclase or potash feldspars, potassium is the distinguishing element, from 6 to 16 per cent being present. Feldspar is not quite so hard as quartz, and is not readily scratched by the knife. The faces of the crystals are flat and glistening, distinguishing it from the quartz. The color is variable, from flesh-colored to white, yellow, pink, or red. Clays result from their rather ready decomposition. *Amphibole* is a type of iron-magnesium-silicate minerals, the most common being hornblende, which is composed of aluminum, magnesium, iron and calcium, which enter the soil on the weathering of the mineral. *Mica* is a complex silicate that is easily identified as it is the only common mineral that splits into very thin paper like elastic leaves. The light colored potassium mica called *muscovite* is used under the name of isinglass or mica in stove doors and lanterns. A dark colored mica containing iron, magnesium and other elements is called *biotite;* that containing lithia is called *lepidolite,* and that containing sodium, *paragonite.* Lepidolite is found in San Diego county as the violet colored gangue rock in which the gem tourmalines are found. Mica is readily seen in many soils as glistening scales, especially in soils derived from granitic rocks, and such soils are said to be *micaceous. Calcite* is calcium carbonate containing 56 per cent of lime and 44 per cent of carbon dioxide. It is the principal constituent of limestone and is easily scratched with a knife and effervesces with an acid, distinguishing it from feldspar. Lime is not only a necessary plant food but also influences in a marked degree the physical condition of the soil, and the process of nitrification. It makes stiff clay soil more porous, more easily pulverized, and therefore more productive. It corrects the sourness or acidity of soils and forms an essential ingredient of all plants. *Gypsum* is the hydrous sulphate of calcium, 32.5 per cent of lime, 46.6 of sulphur trioxide, and 20.9 per cent of water. It is a white mineral, much softer than calcite, being readily cut with a knife. It does not effervesce with acids as calcite does. When calcined and ground it is the common plaster-of-paris of everyday use. It reacts with carbonate of soda (black alkali), forming sulphate of soda and carbonate of lime and is used therefore as a corrective on certain alkali soils. When not calcined but simply ground it is known as land plaster and used as a fertilizer. *Kaolin* is the

hydrous silicate of aluminum, containing 46.5 per cent of silica, 39.5 of alumina, and 14 per cent of water. It forms the basis of clay and is very soft and earthy. It is derived largely from the decomposition of feldspar and is colored generally by iron or other impurities. Pure white kaolin, or kaolinite, is known as china clay and is the basis of pottery work. *Hematite* is iron oxide, containing 70 per cent of iron and 30 per cent of oxygen. It is one of the leading iron ores, occurring in both the hard and soft forms. It gives a red streak when rubbed on a surface harder than the mineral. Iron from hematite is found everywhere, coloring soils and rocks red, yellow and sometimes green. *Apatite* is essentially calcium phosphate with some chlorine or fluorine and about 40 per cent of phosphoric acid so necessary to all plant growth. It is not common in massive form but is fairly common as a mineral in certain rocks. Pyroxene is a type of a large group of rocks, forming iron-magnesium minerals, and is usually a magnesium-iron-calcium silicate. It is not readily identified except by those familiar with mineralogy and its identification in soils is of minor importance. *Chlorite* is a type of a somewhat important group of secondary minerals identified by their green color, softness, smooth or unctuous feeling. They are usually aluminum-magnesium-iron silicates with water which they give up to the soil under decomposition .

ELEMENTS. The minerals that form the rocks are in turn composed of chemical elements. Of all the elements known to the chemists only the following are important in the soils. They are given in the order of their importance in making up the lithosphere:

	Per cent in the lithosphere
Oxygen (O)	47.02
Silicon (Si)	28.06
Aluminum (Al.)	8.16
Iron (Fe)	4.64
Calcium (Ca)	3.50
Magnesium (Mg)	2.62
Sodium (Na)	2.63
Potassium (K)	2.32
Phosphorous (P)	.09
Sulphur (S)	.07
Chlorine (Cl)	trace
Nitrogen (N)	trace

SILICON. The silicon (Si) never occurs in the free state but always combined with oxygen (O) in the form of silica (SiO_2), which unites with other minerals forming *silicates.*

PHOSPHOROUS is present in most soils to the extent of five or six parts per million. It is a plant food that is necessary to all vegetable growth, promoting especially the activity of bacteria, molds and fungi. In natural mineral phosphates the phosphorous is combined with lime, and as calcium phosphate is associated with other minerals to form rock. In artificial fertilizers the phosphorous is combined with lime, iron, or aluminum. Some phosphates such as bones, which are mainly phosphate of lime, also contain organic matter and some nitrogen. Phosphates are not easily dissolved and special agents are used to render them soluble and useful as soil fertilizers.

POTASH exists in most soils in varying degrees. That which is combined with humus material, or with the hydrated silicates is easily set free and easily assimilated as plant food. In finely divided silicates such as clay, (silicate of aluminum) the potassium becomes active as a plant food in a short time, while the potassium in rock debris and sandy soil may be inert indefinitely.

LIME. This occurs in soils principally as calcium carbonate, but it is also found combined with the organic matter as *humates,* with sulphuric acid as sulphate (gypsum) and with silica as silicate of lime. Calcium carbonate, or lime-stone, increases the absorption power of soils, and its presence renders the phosphates, potash, and nitrogen more readily soluble. Its value is not so much for plant food as for its effect upon the physical properties of the soil. It binds the particles of sandy soil together, increasing its water-holding capacity. It helps to granulate clay soils, and stimulates bacterial activity. It neutralizes acids and renders harmless some toxic substances. It helps, under favorable moisture conditions, to humify the soil, giving it the dark color so pleasing to the farmer, as it generally denotes the presence of humus and means fertility.

When lime is added to muddy water the solids settle to the bottom in light fluffy groups of floccules, and a clear liquid is left above. This is called *flocculation.* Mineral acids and most fertilizing material also possess this property: while alkalies prevent and break up flocculation. Soils rich in lime are well granulated and maintain a much better physical condition than soils of the same texture which are poor in lime contents. Large amounts of lime or heavy clay soils have made them much lighter.

MAGNESIA. This generally exists in soils in only small amounts in the form of the carbonate or the silicate. It is more abundant in soils that are derived from mica schists, serpentines, etc. It is not a plant food and is not desirable, even exerting a toxic effect upon some plants. Limestones, raw or burned, that contain magnesia should not therefore be added to soils.

IRON. This element is universally distributed, existing generally as the anhydrous sesquioxide, or as the hydrated sequioxides of the silicates. Plants assimilate iron only in small quantities but it seems indispensable to their development and to the proper functional activity of their assimilating powers. If present in more than small quantities it is harmful for common crop plants.

SULPHUR. This is usually present in humid regions in scarcely more than a trace, enough for all common crops except onions, which require a fairly large amount.

CHLORINE AND ALUMINUM are absorbed and used by plants, but exist naturally in soils in sufficient quantities to supply all demand.

ELEMENTS FROM THE ATMOSPHERE. Ninety per cent of the crop raised comes from the atmosphere and not from the earth. The atmosphere provides an inexhaustible supply of oxygen, hydrogen and carbon, which are the main food of plants, and only ten per cent of the plant food is demanded from the minerals. These minerals exist in nearly every soil *in sufficient quantities* to supply the plants with *food,* and tons of minerals are not needed as *food,* but other material may often be added to soil to advantage in order to improve its *physical condition.* Given the proper physical conditions in the soil and crops will grow and find all the food they desire as a rule. Nearly all so-called wornout soils are simply *abused soils,* and *poisoned soils* whose physical condition only needs to be restored in order to restore their productiveness. It will not do, however, to neglect the mineral matter in all cases, small as it is. For example, we find in bogs vegetation consisting of species that have little mineral in their composition, but we do not find nutritious seeds or fruits or valuable fibres or plants with other useful qualities flourishing where the vegetable mold is so thick as to prevent the roots from reaching the true soil beneath. There must be the admixture of organic and mineral matter ,and a good soil atmosphere as well as free access to the atmosphere above the soil.

NITROGEN is found chiefly in the form of nitrates, and these are very soluble, leaching out of the soils quickly, and cannot accumulate in the soils of humid regions. In its free state nitrogen is not directly absorbed into the tissues of growing plants, but *must be oxidized* before it can be assimilated. It is absolutely necessary to all plant life, as much so as water, and is one of the most costly elements the farmer has to supply. The nitrogen of the air is uncombined with oxygen and is unavailable to the plant. The conservation and increase of the available nitrogen in the soil is most important to the agriculturist.

Rain and snow bring down a small quantity of available nitrogen from the air, but nearly all the supply contained in the soils is derived from combination (oxidation) with the nitrogen of the air, or from decaying animal and vegetable matter.

It is of the greatest economic and biologic value as a plant food and may be present in the soil (1) in organic compounds, (2) as ammonia, (3) as nitric or nitrous acid, or (4) as amido compounds. Each of these four classes may be subdivided chemically, but that belongs to agricultural chemistry and cannot be considered here. The organic nitrogen derived from the debris of animal or vegetable life may be in a form easily rendered available for plant food, or it may be resistant. The ammonia nitrogen is a transition stage arising from decay of incomplete nitrification. It may exist as gaseous ammonia or combined with mineral or organic acids. The nitrogen may be present as nitrous or nitric acid combined with bases, such as nitrate of lime, or nitrate of potash or soda. The amido compounds may exist in varying combinations difficult to understand without a good knowledge of agricultural chemistry.

The minute bacteria present in all soils convert the nitrogen from these various sources into available nitrogen. This process *does not take* place unless the soil is *moist* and has *free air* and some base such as lime present. Nitrification cannot take place unless the soil is in and is kept in the right physical condition. Nitrification is most active at summer temperatures, and ceases at winter temperatures. There can be no accumulation of soluble nitrates in humid climates as there is in the arid and semi-arid regions. Soils are unable to hold the soluble nitrates where there is an excess of water. The available nitrates must pass at once into growing plants, remain in store during *dry* periods, or be

carried away by the drainage waters from storms or irrigation. Some plants, especially those of the leguminous family (beans, peas, etc.) permit the development of colonies of bacteria on their rootlets which have the faculty of attracting nitrogen from the soil air and making it available for plant food. If it were not for such agencies the stores of nitrogen would constantly decrease. Agricultural biology shows that different types of soils have nitrifying organisms of different properties, and that they may be isolated, colonized, cultivated and transplanted.

CARBONIC DIOXIDE—CO_2. This gas furnishes the carbon which is the basis of most plant structures such as wood, cellulose, starch, sugar, etc., and is the material from which the higher plants build their leaves, limbs, trunks and roots. The soil atmosphere contains more carbonic dioxide than the air above, hence the soil solution is always charged with more or less of the gas greatly increasing its power to dissolve minerals. Soils have the power of occluding gases, and this power of absorption and holding depends largely upon the physical condition of the soil. Soils containing a large per cent of silt or clay absorb more than sandy soils.

	Grams water	Grams ammonia	Grams CO_2
100 grams of quartz absorbs..	0.16	0.11	0.03
100 grams of clay absorbs..	2.56	0.72	0.33
100 grams of humus absorbs.	16.01	18.45	2.53

The diffusion of the carbonic dioxide is dependent upon the porosity of the soil, the temperature, and the moisture contents. Pressing or impacting the soil, or increasing the water, is followed by decrease of the diffused gas. Diffusion is also less where the drainage is poor and the waters percolate slowly. The percentage of organic matter in excess does not indicate the per cent of carbon dioxide present. The gas may come from the irrigating waters, from the air, from decaying animal or vegetable matter through bacterial action, or from fertilizers.

CHAPTER III

LAND FORMS

The description, classification, and correlation of land forms is called *geomorphology*. The earth seems to be solid, stable, and fixed to the last degree: yet it is really unstable and ever in motion, both as a whole and in all its parts. Astronomy shows that the sun, moon, planets and stars are unceasing in their course. Chemistry shows that the countless atoms and ions form molecules only by a ceaseless motion that makes each particle of matter, each grain of soil a little cosmos. Molecules of the elements make up minerals, aggregations of minerals make up rocks, and rocks make up land forms. Geology shows that the earth is slowly cooling and contracting and ever adjusting its parts to this stress and strain. Lands emerge from the sea, and mountains are lifted up only to be at once attacked and slowly destroyed by atmospheric agencies.

A glance at a relief map shows that the earth is not smooth but has an irregular surface of relief and depression forming hills and hollows of all sizes and shapes. These are known as *land forms* made by tearing down the rocks that make the high places, and the filling up of the hollows and low places, and covering the flats with soil. Each type of land form has its own type of soil, for similar causes give similar effects.

PLAINS, or lowlands, are broad, smooth, level, or gently sloping tracts of land not far above sea level. They are generally overspread with a deep layer of mantle rock brought down from the higher lands by streams and winds, or produced by the decay of the bedrock beneath. The term is loosely used, for there are hilly and rolling plains as well as level ones, high as well as low, and small as well as large.

STRUCTURAL PLAINS. Most plains are underlaid by undisturbed sedimentary rocks, and the flat surface conforms to the flat lying rocks beneath.

COASTAL PLAINS, or former marginal sea bottoms, are formed by the slow rising of the sea bottom, and are covered with

imperfectly consolidated sediments which have been washed down from the older lands and deposited off shore. Coastal plains may be recent additions to the continent and are geologically said to be *young;* or they may be *old* and occuring in the interior of the continent far from any ocean of today. They may be peneplains, the result of the filling of sea borders by wash from adjacent mountains, or high lands, as the coastal plains of southern California.

DEGRADED PLAINS were once high, rough regions that have been worn down to flatness and low elevation by erosion, the work of weather, streams, glaciers, etc. They are seldom as smooth as coastal plains, but are studded with low rounded hills, due to their material being harder. These are called *worn down plains* or *plains of degradation.*

ALLUVIAL PLAINS. Large rivers in times of high water spread over the adjoining country and deposit coats of sand and mud, building up what are known as *flood plains.* The flood plain formed at the mouth of a river where it drops the load of sediment that it has carried is called a *delta,* as the delta of the Colorado River.

LAKE PLAIN. Streams in time fill up lake basins with sediments converting them into an almost perfectly flat *lake plain* or *lacustrine plain.* Lake Tulare is slowly evaporating and being filled up and converted into a lacustrine plain. Many farms and ranches in the state are being cultivated where lake waters once stood.

GLACIAL PLAINS. The ice sheets that once covered the Sierras melted and deposited vast sheets of mantle rock called *glacial drift* which filled up the irregularities of the surface, forming *glacial plains* or *drift plains.* Such plains are of minor extent and importance in California but may be studied in the Sierras and in the northern portion of the state.

EOLIAN PLAINS. In the arid regions, misnamed deserts, the loose mantle rock is lifted, drifted, and carried away by the winds, producing a *worn-down plain* studded with knobs of resistant rock called *wind-worn rocks,* and the materials accumulate on neighboring lands forming a mantle of fine sands. Both the wind-worn, and the wind-filled plains are called *eolian plains.*

PLATEAUS. A plateau is relatively an elevated area of

comparatively flat land. There is, however, no fixed line between plains and plateaus, for in a region of low relief like the east, a broad, massive, high plain at an elevation above 1000 feet may be called a plateau; while in a region of high relief like California, the same name would scarcely apply to anything at an elevation less than 2000 feet above sea level. Low plateaus may be called *uplands,* and higher plateaus called *highlands.* They may be as smooth and level as a plain, but are usually more broken, and some are deeply trenched with valleys.

MOUNTAIN. A mountain is an elevation rising prominently above the surrounding area. Mountain ranges are long, narrow ridges of great height, caused by the upheaval of the earth's crust, but their forms are due chiefly to erosion. *Isolated mountains* that do not form part of a range, are either remnants left by erosion, or they may be of volcanic origin.

HILLS are little mountains. In a region of low relief, hills 1000 feet high may be called mountains, as in Pennsylvania, but in a region of high relief like California, ridges 2000 feet high are often called hills; for example, the foothills of the Sierras. Hills are often due to the cutting out of the valleys between them, or to the heaping up of the mantle rock, by ice sheets, winds, etc.; hence they may be *hills of erosion,* or *hills of accumulation.*

VALLEYS. These are the most common of relief forms. Many of them have been made wholly or partially by running water. Valleys that lie between mountain ranges are called *intermont valleys.* Those formed by the arching down or synclinal formation of the bedrock are known as *structural valleys*: thus the Great Valley of California is both an intermont and a structual valley.

BASINS are areas of deficient drainage, having no outlet to the sea, hence the water must be retained until evaporated.

BOTTOM LANDS are built up by long continued deposition of river sediments to a considerable height above the adjacent lower valley plain.

BASE LEVEL. This is the plain below which erosion cannot proceed, the final base level being sea level. There may be a number of local base levels determined by the outlet of each stream, but only one general base level. The base level is not a topographic form but a mathematical plane which may or may

not, and generally does not, coincide with a land surface. A *base leveled surface* is any land surface, however small, which has been brought approximately to a base by gradation. If the area is large it is a *base leveled plain.* A *peneplain* is one which has in general been reduced to a base leveled plain, but also contains some unreduced residual areas.

BROKEN BLOCK LANDS. In some regions the earth's crust has been broken into blocks by nearly vertical cracks, very much as an ice field is broken into cakes. These blocks have been displaced, some upward, some downward, and others tilted on one side, just as ice is tilted. The cracks are called faults. The elevated block may form steep sided table lands, and if tilted they form sharp crested ridges, but if depressed they may form basin or rift-valleys. The Sierra Nevada is a faulted block and the eastern side has been tilted up, forming a short steep slope, while the west side is long and slopes at a low angle. Many of the ranges of the Great Basin are tilted blocks, and the Island of San Clemente is a good example. The subsidence of a long narrow block between two or more fault lines produces rift valleys such as the one commonly known as Death Valley, between the Panamint and Funeral ranges, a part of its surface being below sea level.

VOLCANIC LANDS. Volcanic eruptions produce a relief of conical and dome elevations standing singly or in groups, as may be seen at Mt. Shasta or at Lassen's Peak. Streams of lava flowing from the vents have flooded thousands of square miles to a great depth, building up lava plateaus with a comparatively smooth surface, as in the northeast corner of the state. Volcanic action is constructive more than destructive, and is a great builder of relief land forms. Lava beds weather and crumble into rich soil of great agricultural importance, and volcanic dust, miscalled ashes, is carried by the winds broadcast over the land, renewing the soils. Volcanic matter may be fluid, filling and choking original river valleys, or covering plains with a flood of molten rock. Good illustrations of this are common in the great placer regions of the Sierras. The molten matter may be blown to fragments by the escaping steam, forming showers of so-called ashes which cover the earth like sand. This volcanic ash is very light and the particles cohere readily, and the decay is slow at first and then rapid. They are easily washed away by

rains. While they seem to be glassy they contain considerable amounts of lime, potash, soda and iron, which are added to the soils. As shown elsewhere, volcanoes have added largely to the agricultural wealth of this state.

ECONOMIC. Alluvial, lacustrine and glacial plains are the best agricultural regions in the world on account of the depth and fertility of the soils. Coastal plains come next in value, except where irrigation places them in the front rank. Worndown plains are often useless for agriculture on account of the shallowness of the soil, but they sometimes support forests. Eolian plains are generally arid regions, not on account of lack of fertility in the soil, for they are exceptionally fertile, but for lack of water for irrigation. Plateaus are less favorable for agriculture on account of the rougher surface, poorer soil, and colder climate. The soil on mountain slopes is thin and poor often, and there are large areas of bare rock; the climate may be severe, and the seasons short. Agriculture is impossible high up in the mountains except in some of the sheltered valleys. Mountains are the great soil factories where the bedrock is rapidly broken up and carred away by the streams to renew the soil in the valleys and on the plains below.

PART II

CHAPTER IV

PROCESSES

In order to trace the erosion, drainage development, and origin of the present land forms, and of the soil that covers them we must study the processes by which these forms have been developed and the agencies used. This study is known as *geomorphogeny.*

VIRGIN SOIL. If we take up a handful of soil and examine it the eye alone shows that it is made up of bits of matter, decayed leaves and twigs, blackish mold and stony particles of various sizes and shapes. Under the microscope we see that decay is breaking up these stony particles along their edges, joints and cleavages. The soil particles are ever being broken up into still finer states of division. Mountains are destroyed, hills disappear, valleys are filled up by agencies that seem at first to be wholly destructive. The very processes that we call destructive, however, and associate with death, are in fact constructive and associated with life. They are but changes, steps forward, not backward, which bring matter from the lower mineral state up to the higher condition of soil and ready to take the next upward step into plants and animals, into organic living forms.

The physical properties of soils depend upon the processes by which they were formed, and we must know these processes in order to classify the soils, as their classification is necessarily linked with their derivation. Changes in the underlying material, in the rocks or subsoil below, are largely responsible for the many varieties of soils known; and the processes which gave this material its present character determine the class to which the soil belongs. The factors involved in the processes vary with the climate, so that soils formed under arid, semi-arid, or subhumid conditions are always different from those occuring in regions of heavy rainfall. The soils in a region of low rainfall always contain a larger per cent of soluble material than those of the more humid regions, but lack the irrigating waters to make them available.

THE ATMOSPHERE acts directly in forming soils (1) as a mechanical agent, (2) as a chemical agent, (3) it furnishes the conditions under which the sun produces temperature, (4) it controls evaporation and precipitation.

WIND EROSION is the mechanical action of the atmosphere. Rocks are worn away and converted into soil by the abrasion and impact of wind-blown dust and sand. In the arid regions, cliffs, hills and ranges are worn away by the sand blasts.

CHEMICAL WORK OF THE ATMOSPHERE. The important chemical changes wrought by this agency, generally in connection with water, are *oxidation, carbonation* and *hydration.* Iron salts are oxidized and color the soils red, and other salts are slowly oxidized or converted into carbonates. Water dissolves salts in the soils and the solution is drawn to the surface by capillary action where the salts are left in a hydrated condition. Agricultural chemistry is largely a study of the myriad forms of these chemical changes.

DUST is an example of the mechanical action of the atmosphere. A feeble wind moves particles of dust, a moderate stiff breeze shifts dry sand, and a very strong wind moves small pebbles. Beds of volcanic dust thirty feet deep occur in Kansas and Nebraska, hundreds of miles from the nearest known volcanic vents, and the material has evidently been carried there by the winds. Many of the soils of California are rich from this wind-transported volcanic dust. Much of the famous loess deposits are evidently eolian. Dust forms films and layers everywhere, even on the bottoms of lakes, and is ever taking from or bringing to the soils some material every year.

DUNES. The winds do not often lift sand far above the surface of the land but move it along and raise it into mounds and ridges, like drifted snow, which are known as *sandunes.* These dunes sometimes invade fertile lands causing great loss unless checked. On the other hand this sand often does great good, for blown onto clay soil and silt soil it gives them a loamy character and improves them.

TEMPERATURE. The daily range of the temperature is influenced (1) by the latitude, (2) by the altitude, and (3) by the humidity. The lightness and dryness of the air at high altitude allows the heat to radiate rapidly at night and the nights are cool or cold. The rocks expand under the heat of the day and

contract under the cold of the night, causing the surface to crack and scale off, forming heaps of debris at the feet of the cliffs. The expansion and contraction of such cliffs as those of the Yosemite is far greater than the uninformed would think possible.

High temperatures favor chemical action and rocks weather faster in regions of abundant moisture and high temperatures. The rocks of the foothills below Mt. Shasta weather much faster than the rocks in the arid portions along the Colorado River. A moist climate favors the growth of vegetation and its decay supplies organic acids to increase the solvent powers of the waters; thus the rocks of the tropics are decomposed to greater depths than those of the northern latitudes. A moist atmosphere favors oxidation, carbonation and hydration and the greater growth of vegetation, which in turn promotes rock-weathering and soil-forming.

Lands sloping toward the sun are warmer than those sloping away from it, as the south side of a hill is warmer than the north side. Dark colored soils absorb more heat than light colored soils and retain it longer.

The temperature of a soil is raised by fermentation and decay of vegetation and animal matter, a fact taken advantage of by those who raise mushrooms. While these factors affect the character of the soil, the temperature of the soil in turn affects greatly its adaptability to crops. Few seed will germinate if the soil temperature is below 45 degrees F, and from 65 to 100 degrees F is more favorable. Gravelly and sandy soils are warmer than clays. Wet soils are cold because much of the heat received from the sun is used in evaporating the water; hence soils are warmed by draining them.

WEATHERING OF ROCKS. Bedrock exposed to the weather, that is to the action of sun, air, and water, is decomposed into rock waste or loose material. The oxygen of the air attacks some of the rock minerals, oxydizing them, as when iron is oxidized, or rusted, and falls into a red powder. The carbonic acid gas of the air combines with lime forming carbonate of lime, which is dissolved by water and carried away. Rocks expand under the heat of the sun by day and contract by night, cracking, peeling and scaling. Water drains into the cracks by day and freezes at night in the cracks and pores, splitting the rocks. Sands blown by the winds erode them, or lodge in the crevices and fur-

nish a soil that plants grow in only in turn to attack the rock. Roots penetrate the minutest crevices, and, growing, crack and split the rocks, and the vegetable acids secreted by plants dissolve the minerals. Water dissolves out caves and undermines cliffs. Ice and snow shove and push rocks from their places.

The combination of these and other destructive processes is called *weathering*, and the products are sand, clay, gravel, pebbles, boulders, silt and soil.

WATER plays the most important part of any single substance entering into the structure of the earth. It has the widest distribution and is everywhere in relatively rapid motion. In the gaseous form it escapes from the bosom of the ocean, from the surface of the soil, from the foliage of vegetation, and from the bodies of animals, to rise to varying heights above the surface of the earth and to be precipitated as rain, hail or snow. It is the constant evaporation of water from the sea and its return to the land and the leachings of the soil that keep both the soil and the water at the standard of purity which is essential to all the life of the land areas.

RUN OFF. A part of the rainfall sinks below the surface into drainage channels or is absorbed by the soil and rock mantle. A part runs off the surface at once, and a part is evaporated. The water that does not sink into the ground but flows away is called the *run off*. The ratio of the run off to the rainfall varies with the slope of the land, its relief, geologic structure, climate and vegetation. The steeper the slopes, the more rapid the rainfall, the less porous the soil, and the less the vegetation, the more water will run off without sinking beneath the surface.

MECHANICAL WORK OF WATER. The rain washes the atmosphere, carrying down dust, smoke and gases onto the soil. Some of these gases, such as the carbon dioxide (CO_2), dissolve mineral matter in the rocks and soils. Clayey soils baked by the sun are softened by the rain and are then easily removed by running water. The expansion and contraction caused by alternate wetting and drying cause the soils on slopes to creep downward. This is called *soil creep*. When rain falls on dry sand or dust the cohesion of the particles is increased and shifting by the wind is checked for a time. Drops of water fall with a certain force which may seem of slight importance but which is really of great

moment. In a heavy rain, drops cut clods to pieces rapidly. A flat stone may protect the soil and be left at the top of a little mound of earth, or even form the top of a large pinnacle in the course of time.

Rain drops have a disrupting effect that promotes the rapid washing of the soils. The first effect of *erosion* by water is to roughen the surface by cutting valleys, and leaving ridges. The final effect is to make all smooth again by leveling the ridges and hills and filling up the valleys and hollows. On bare mountains the heavy rains wash the soil down to lower elevations. Brush and forest prevent the rain from cutting the soil to pieces and from spreading in sheets and washing the soil away.

SOLVENT ACTION OF WATER. All waters, rain or spring water, contain more or less mineral matter in solution. Hard or soft water means that the water has much or little carbonate or sulfate of lime or of magnesia in it. This dissolved mineral matter is left wherever the water evaporates. Water containing carbon dioxide is a strong solvent of the carbonate and phosphate of lime and of the salts of magnesia and iron.

Decaying vegetation acts upon rocks through the carbon dioxide set free. Decay of nitrogenous matter gives rise to nitric acid, which dissolves mineral matter in the soil. Soils formed in the arid regions where the solvent action of the water is small are distinctly sandy and the particles are sharp. Soils formed under subhumid to semi-arid conditions always vary from those in the humid regions. In the regions of heavy rainfall the more soluble materials are leached out by the carbonated waters, leaving the more siliceous matter. The soils of the drier climates retain and contain therefore a larger percent of soluble material and wait only for irrigating waters to make this material available for crops.

STORAGE OF WATER. When sediments are laid down in the ocean, or in gulfs and bays, there is locked up in them large volumes of water varying from 25 to 50 per cent of the volume of the sediment, according as the pore space is large or small. All rocks contain more or less water, even hard marble absorbing 0.23 per cent of its weight. The storage capacity of soil generally is in round numbers two feet of water to five feet of soil. Sand and sandstones lying below drainage outlets may contain as high as 38 per cent of their volume of water, and become storage res-

ervoirs of great capacity. Clays range from 20 to 40 or even 50 per cent of their dry weight in stored water.

AIR RETAINED. The capacity of water to retain air condensed within itself increases with the air pressure to which it is subjected. Air does not readily escape from the spaces of a fine grained soil, especially when the soil is saturated with water.

ICE BENEATH THE SURFACE. The water which freezes within the soil has an effect upon the surface. Stones and boulders work up through the soil as freezing and thawing alternate. The frozen water in the soil makes it solid and prevents surface erosion. If the water in ponds, streams and lakes is shallow the water freezes to the sand and gravel and boulders at the bottom, loosening and moving them.

WORK OF UNDERGROUND WATER. Rain water is pure, but water from wells and springs contains mineral matter, showing that the rain water after sinking underground has dissolved mineral matter. One mineral in solution may be exchanged for another, the lime carbonate of a shell may be removed particle by particle, and some other mineral such as silica be left in its place; or cementing material may be deposited in a soil, forming a hardpan. Materials taken from rocks in one place may be added to a soil in another place. Rock minerals in one place may be made porous, making the soil lighter; and in another place the pores of the soil may be closed, *indurating* or hardening the soil. New minerals are developed out of the old by addition, subtraction, or division of the minerals. In fact the mantle rock of soil and subsoil represents the residium of this working over of the material from the bedrock, or of the original material before it is transported to the soil area where it remains.

The underground water moves large masses of material at times. It saturates masses of earth and rock, increasing the weight and destroying the adhesion between layers, as where rock or soil rests on clay, and masses give way, forming *landslides.* Streams of stones moving steadily but very slowly down steep slopes are a form of slide called *screes.* At the foot of cliffs and steep slopes there is generally a *talus,* or heap of rock fragments fallen from above.

DRAINAGE. When a land surface is young, or recently elevated above the sea, the run-off fills the depressions, forming

lakes, ponds and marshes. On the low plains, drainage develops slowly and remains imperfect for a long time. The shallow lakes of the glacial drift high in the Sierras are being slowly filled with mud and peat which will form soils there in the future.

The diameter of the soil grains and the amount and form of the pore spaces determine the amount of water which can pass through a soil in a unit of time. The pore spaces are determined by both the size and the arrangement of the soil particles, and may vary from 25 to 45 per cent of the volume of the soil. Underdrainage removes water from all except the capillary spaces and leaves the other spaces free to air circulation. There is also an upward movement of the air from the drains to the surface which aids in the aeration of the soil. *Seepage* is the movement of water through the fine pores of the soil under the stress of gravitation. It begins when water enters the soil and ends where the water escapes into passages larger than capillary. The moving power is the hydrostatic pressure of the water itself, and this pressure is increased or lowered according to the pressure of the atmosphere, varying with high and low barometer. The flow of water from tile drains will vary as much as 15 per cent with the barometric changes.

GRADATION. The run-off forms streams, and a stream in times of flood cuts its channel deeper, and the overflow deposits sediment on the adjoining floodplain. In other words the stream in flood *degrades* or scours its channel, *aggrades* or fills up its plain. As a result of its varying velocities in flood and in low water, a stream may deposit coarse material at one time, and fine material at another. Floodplain deposits, or soils, therefore vary from the finest mud, through sand and gravel to boulders. When a rough piece of land is prepared for irrigation it is graded by cutting down the high places and filling up the low. The same process is going on all over the world, mountains, plateaus, and hills are being worn down and the material deposited in valleys, basins and over the lower plains. Lowering the level of the land is called *degradation,* and raising the level is called *aggradation,* while the result of the two processes is called *gradation.* As a country grows smoother and is reduced by gradation to a plain of low relief, not far above sea level, it is called a *peneplain* (almost a plain). Young low plains are smooth and gently sloping, easily accessible, easily cultivated and generally productive.

STREAMS. If any stream is followed up it is found to divide into smaller branches and rivulets, as a tree divides above the trunk into branches and twigs. Take any of the rivers for example. Near its source in the high Sierras the slopes are steep, the current swift, the channel narrow or *canyon* like, and are filled with boulders: lower down the slope is more gentle and the water course consists of a wide *outer valley* which the stream covers only at high water, and a narrower *channel* winding irregularly from side to side; still lower the valley becomes very much wider and consists of an extensive *floodplain*, and the channel follows a meandering course full of bends and horseshoe curves; and finally the river reaches the sea through a delta or a series of sloughs and bayous.

TRANSPORTATION OF SEDIMENT. We generally think of a stream as a stream of water only. It is also a stream of mantle rock or soil held in *suspension*. Streams are the circulation system of the earth, carrying nourishment to all parts. In the human system the blood goes from the heart and carries in suspension the digested foods to all parts and picks up and carries away used-up products, until the life-giving stream is overloaded. Then it passes into the lungs and the impurities are burnt out by the oxygen of the air. The rains descend upon the mountains and form streams that take up soil material, plant food, and carries this down and distributes it where it is needed, and also picks up its loads of used material, or waste, until overloaded it dumps itself into the ocean where the waste material is washed out.

The ocean is the great septic tank of the world. Here waste material is deposited to form sediments or soils for generations yet to come. Evaporation carries the pure water up to the clouds and back to the mountains, to be precipitated again, completing the cycle of the waters.

Thus the surface of the earth, the soil, is the growing, living, changing part with its circulation system that is analagous to the blood of animals and the sap of vegetation .

The size of the rock particles which a stream can carry in suspension increase as the speed of the current increases. A current of one-third of a mile per hour can carry clay; two-thirds an hour can carry sand; two miles per hour, pebbles the size of a bean; four miles an hour, stones the size of an egg; while a mountain torrent will move huge boulders.

A stream carrying all the sediment it can is said to be *loaded*, or it may become *overloaded* and have to deposit some of its burden.

DEPOSITION. A stream flowing down a steep hill or mountain side erodes a gully, or canyon, and deposits at the mouth of a gully a conical or fan-shaped heap forming an *alluvial cone*, or flat *fan*.

Illustrations of this may be seen on a small scale anywhere after a rain.

The rivers descending from the great Sierras build extensive fans at the base of the range, such as that of the Merced River which has a fan with a radius of 50 miles. Where the alluvial fans are so large as to join, forming a continuous plain, such as are found all along the east side of the San Joaquin Valley, or the base of the Sierra Madre, it is called a *piedmont* (foot of the mountain) *alluvial plain*. These are easily irrigated as the water spreads naturally over the land and can be easily carried to any part. When a stream overflows its banks it deposits sediment on the flooded ground forming an *alluvial plain*. At the mouth of the river the alluvial plain extends into the lake or sea, forming a *delta*. At the head of the delta the stream often divides into *distributaires* and enters the sea or lake by many mouths. The soil of a flood plain, or of a delta, is often so fertile that it pays to protect it by *dikes*. Streams towards their mouths may become overloaded with sediment, the channels become shallow and crooked and constantly changing and in some cases the river becomes divided into a network of small streams and is said to be *braided*.

RECENT STREAM DEPOSITS. With every heavy rain the streams traversing the foothill valleys become heavily laden with sediments washed from the surface of the bordering slopes. Upon entering the valley, the streams overflow their banks, the water spreads, the velocity of the current is suddenly checked, and the coarser sediments, consisting say of fine sands and silts, are deposited, covering the original material of the valley slopes with a thin layer. In this way some of the streams have built up along their flood plains a slight ridge, the summits of which they traverse, until the slopes of the stream beds reach a minimum, when they break through the enclosing ridge, seek new channels, and build up other low broad ridges. These streams finally enter

the valley trough where the drainage is deficient and water frequently stands during the rainy season, and it is here that the finer silts and clays are deposited.

CROOKEDNESS OF STREAMS. The current of a winding stream is swifter on the outside of the bend, and it cuts the bank there and deepens the channel. The slower current on the inside of the bend drops its part of the load, building up a *bar* of mud or sand.

VALLEY FORMS. A swift stream uses the sand and gravel it carries as tools that saw their way down through the hardest rocks. Thus the region through which the Colorado River runs in Colorado and Arizona is slowly rising, and the river cuts its way down, ever deepening its canyon. A swift stream cuts the bottom faster than the sides, cutting deep narrow valleys such as are found in the canyons of the Sierras. A slow stream cannot sweep the bottom clear, and winds cutting the sides and wearing away its banks, forming in time a wide valley. A stream which is actively deepening its valley is *young*. A stream which has cut its valley down so as to smooth out its falls and rapids has reached *base level* and is *mature*. A stream which has widened its valley and aggraded its flood plain has reached *old age*.

LEVEES. As a river overflows its banks, the current is checked rather suddenly and the larger and coarser sediment is dropped near the channel, thus building up a bank above the level of the flood plain, forming a natural *levee*. The floods leave a thin layer of fine fertile mud or silt over the submerged land, forming a soil of great fertility that is often renewed.

LAKES. Lakes, ponds and marshes are bodies of standing water which occupy depressions in the surface of the land. They are never stable, but are ever changing. (1) Waves wear the shore and the material from this is assorted and deposited; (2) streams carry their loads of mud, sand, and gravel into the lakes and leave them there; (3) winds blow in sand and dust; (4) animal forms of life live and die there leaving their bones or shells; (5) plants grow in the shallow waters and their material accumulates on the bottom; (6) the lake is drained by the cutting deeper of the outlet; (7) in cold regions ice crowds the shores and effect changes; (8) in the arid regions minerals are precipitated from solution. All this accumulation of material raises

the bottom of the lake and reduces the water capacity of the basin. If the rainfall exceeds the annual evaporation, and the outlet cannot carry off the water the lake increases in size, spreads out over more land, but is shallower; plants accumulate, and a marsh peat bog, or meadow is formed. Where the sediments deposited in the lakes are made up largely of the shells of fresh water animals, the calcareous secretions of plants, or lime precipitated from solution, such deposits are called *marl* if they are soft.

In the arid regions where the evaporation exceeds the rainfall, the depressions in the floor of the basins fill up with water in the wet seasons and evaporate in the dry seasons, leaving bodies of salt, soda, borax, etc. These are properly called *intermittent lakes,* but are locally known by many names, such as "dry lake," "soda lake," "borax lake," "alkali lake," "desert sink," etc. *Glacial lakes* are hollows in the bedrock eroded by moving ice, or hollows made by deposits of drift forming dams. Examples are numerous in the higher portions of the Sierras. *Volcanic lakes* are old volcanic craters filled with water: or are caused by the damming of a stream by a lava flow.

GLACIERS. These ice streams are slow, stiff and awkward compared with a river, but are prominent factors in the making of many soils, as they are great soil mixers. A glacier tears loose rock fragments at its head, eating slowly into the mountain side, forming a vast hollow called a *cirque,* and the ice stream several hundreds of feet in depth grinds the rock underneath into flour called *bergmeal.* The thick accumulations of drift at the end of a glacier, or edge of an ice sheet, is the *terminal moraine.* A glacier does not have the sorting power of water so that its material is a mixture of all kinds of rocks, cobbles, pebbles, sand and clay confusedly intermingled from the finest to the coarsest and is easily recognized as *glacial drift.* The land worn down by glacial action is left barren bedrock, or with a thin mantle of coarse material, rendering agriculture impossible. The vegetation of such a soil generally consists of coniferous forest. The bulk of glacial drift is composed of *boulder clay,* a stiff clay containing pebbles and boulders. Glacial drift ridges are called *marginal moraines,* formed along the edges of the melting ice sheets, *kames* are the irregular heaps of sediment formed where water escapes from the ice, *eskers* are sharp winding ridges of sand and gravel

deposited in stream channels under the ice; and *drumlins* are lenticular or prismatic hills of clay. Glacial streams are as a rule aggrading streams and develop alluvial plains called *valley trains,* or deltas, where they enter lakes, bays, or other streams.

The soils of California owe much to glacial action, for glaciers not long ago covered large portions of the higher ranges, and small glaciers still exist on the sides of Mt. Shasta where their action in soil forming may be studied. The glacial lakes near Lake Tahoe and at the head of the Yosemite Valley give excellent opportunity to study moraines, kames, eskers, and drumlins.

CHAPTER V

CALIFORNIA TOPOGRAPHICAL PROVINCES

California is the result of the geologic forces of the past, and the agencies at work today. It is not to be expected that the geologic history of all parts of such a vast area are the same. The regions or large areas having the same history are known as *provinces*. These provinces may be studied according to their relief forms or topography and climate, or according to their geologic history. Considering first from the topographic standpoint we find abundant reasons for its diversity in soils and crops.

AREA. California lies between the parallels of 32 degrees, 30 minutes north latitude and 42 degrees, thus stretching through nine and a half degrees of latitude. This line on the Atlantic coast would reach from Edisto Inlet in South Carolina to Cape Cod, Massachusetts.

The extreme distance from the northwest to the southeast corner is 775 miles. The maximum width is 233 miles, and the minimum is 148. The total area is 158,360 square miles, of which the land area alone is 155,980 square miles. The coast line along the Pacific measures 1,200 miles. It is larger than the combined areas of New York, Massachusetts, Connecticut, New Jersey, Delaware, Maine, Vermont, New Hampshire, and Ohio. If one considers the diversity of soils existing in all the states mentioned, it is natural to expect so large a state as this to contain a very wide range of soils. It is naturally divided into six provinces, each of which has some soils not found elsewhere, and other soils in common with other portions of the state.

THE SIERRA NEVADA PROVINCE. The Sierra Nevada range is not only longest in the state but it is the highest in the United States, forming a gigantic wall along the eastern edge of the central portion of the state. In form, it is like an immense and irregular lense-shaped table that has been tilted up along its eastern edge, showing a bold precipitous face to the desert on the east, but sloping as a whole gently towards the Great Valley on the west.

The Range proper terminates on the north near Lassen Peak, and on the south at Tejon Pass. The crest lies close to the eastern edge and its skyline is marked by hosts of snow-clad peaks towering from 10,000 to 13,000 feet above the sea, culminating in Mt. Whitney, 14,502 feet above the sea.

The rainfall among the peaks ranges from 70 inches in the northern part in Sierra County to 60 in Eldorado County, and 50 in Madera County. It diminishes from this to the rainfall of the foothills bordering the great valley on the west. Few realize the extent of the great watersheds included in this mighty range, or the volume and value of the streams descending from it. The following areas were carefully computed by state and national engineers, and measure the watersheds from the edges of the valleys to the head of the streams. Beginning on the north and coming south the tributaries to the Sacramento River from the Sierras are as follows: Feather River 3654 square miles, Yuba 1358, Bear 287, and American 1899. The tributaries to the San Joaquin River are: the Consumnes River 580 square miles, Jackson 283, Mokelumne 657, Calaveras 491, Stanislaus 1051, Tuolumne 1501, Merced 1076, Chowchilla 268, head of San Joaquin 1637, Kings 1742, Kaweah 619, Tule 437, and Kern River 2345 square miles.

The San Bernardino, Sierra Madre, and San Jacinto ranges are the southern extension of the Sierra Nevadas, and their geologic history is closely the same. They range from 5000 to 10,000 feet in height, culminating in Mt. San Bernardino (Grayback) 11,725 above sea level. They are drained by the Los Angeles River 568, San Gabriel 512, Santa Ana 1540, Santa Margarita 731, San Luis Rey 566, San Diego 409, Sweetwater 216, Otay 145, and the Tia Juana River 499 square miles of watershed.

The Sierras are covered with the National Forest Reserves and are given up to lumber, cattle and sheep industries, with more or less farming in some of the valleys.

THE COAST PROVINCES. The Coast Ranges include all of the mountain ranges lying west of the Great Valley and the other provinces and extending to the ocean. There is no well defined central axis, either topographic or geologic, but the range consists of a number of parallel ridges 3000 to 4000 feet high, with occasional peaks. The rivers are short and the drainage areas much smaller than those of the Sierras.

The northern Coast Range, or that extending north from San Francisco, is drained principally by the Eel River which has a basin of 3,552 square miles, the Mattole has 225 square miles, the Novo 126, Big 164, Navarro 248, Russian 1515, Gracia 82, and Gualala 351. The rainfall varies from 40 inches near the coast to 30 inches on the eastern side. While lumber, cattle and general farming predominate in the northern portion of the range, the central and southern portions are noted for their extensive orchards, vineyards, and intensified farming.

The south Coast Range extends from San Francisco to San Diego and is drained by numerous short but important rivers that supply water for irrigation. At the south end at San Diego this range merges with and forms the foothills of the southern Sierras and the rivers are classified with the Sierras. With this exception the drainage areas are as follows: Guadalupe River 201 square miles, Pescadero 80, Salinas 4714, San Luis Obispo 78, Santa Maria 1806, Santa Ynez 836, and Santa Clara 1576 square miles.

The rainfall in the mountains is from 30 to 50 inches, varying with elevation. In the foothills it is from 20 to 30 inches; and in the valleys from 10 to 20 inches. The valleys are relatively broad and of gentle slope, and in general given over to intensive cultivation under irrigation of crops that are specified in connection with the soil descriptions.

THE GREAT VALLEY. One of the most striking features of California is the great central valley, some 400 miles long, which extends for nearly two thirds the length of the state. It lies between the Sierras on the east and the Coast Range on the west. The northern portion is drained by the Sacramento River and the southern portion by the San Joaquin, the two rivers meeting close to the point where they empty into San Francisco Bay. These rivers are fed by the many large streams already mentioned in the Sierra Province. The Coast ranges supply only a small amount of water to the valley. The Great Valley is a great synclinal trough partially filled with the debris from the gradation of the ranges that enclose it.

The elevation varies from slightly above sea level to below mean tide, near the bay, and to about 100 feet above sea level at Marysville Buttes, and 800 feet a little ways north of Redding. The San Joaquin valley is only 420 feet above sea level at Bakers-

field. The middle or bottom of the valley is a vast plain without rock outcrops, bluff, or terrace, with sluggish streams and tidal sloughs. On either side are the uplands, consisting of rolling, sloping plains which reach to the foothills. The rainfall at the north end in Shasta County is from 30 to 50 inches, decreasing towards the south to from 10 to 20 in the central portion, and from 20 to 30 inches along the bordering foothills. The crops are described in detail in connection with the soils.

THE GREAT BASIN. This is the western portion of the great Cordilleran region that has no outlet to the sea, and extends from the foot of the Sierras to the eastern boundary of the state. The northern portion is small, covering the region from Honey Lake in Plumas County to Goose Lake in Modoc County. The southern portion covers most of Mono, Inyo, San Bernardino, and Imperial Counties, the eastern portion of Riverside County, the northern portion of Los Angeles County, the southeast part of Kern County, and a part of the east edge of Ventura County. It is not a cup-shaped depression gathering its waters at a common center; neither is it a vast level covered by desert lands. It is a broad area of varied surface, valleys, plains, mountains, and many independent drainage districts, and contains many important communities of prosperous people. Its general elevation in California is from 4000 feet above sea level in the northern portion to 2000 feet in the southern portion, descending finally to sea level and even below. Isolated mountain ranges rise from 2000 to 3000 feet above the general surface of the basin. Between the ranges are smooth valleys, whose alluvial slopes are floors built up of debris washed through long ages from the ranges. These valleys are generally trough-like, merging enough to assume the character of plains. Locally they have been miscalled deserts, as the Mojave, Amargosa, and Colorado deserts, the proper name being arid districts; for under irrigation, prosperous communities now occupy extensive portions of the former so-called "deserts."

The lowlands and mountains are generally treeless, except for fringes of cottonwoods along the streams and straggling brushlike cedar in the mountains. The rainfall averages from 2 to 5 inches; but the storms result mainly from the irregular and often violent local disturbances in the mountains and sooner or later the "cloud burst" visits every locality.

The aridity is most apparent when compared with that of the

great plains lying between the Mississippi River and the Appalachian mountains of the east. On the eastern plains the average moisture contents of the air is 69 per cent of that necessary for saturation and rainfall: in the Great Basin it is 45 per cent. The rainfall of the plains is 43 inches, and that of the Basin from 2 to 5. The evaporation from the surface of Lake Michigan is a layer of water 22 inches deep; from the Great Basin it is 80 inches per year in the north and reaches 150 inches in the south.

Owen's River Basin is one of the minor divisions of the Great Basin. It lies at the eastern foot of the Sierra Nevada in Inyo County, just east of the highest peaks in the United States, Mt. Whitney (14,502) and Mt. Lyell (13,090), and has a watershed of 2630 square miles. While the river is only 125 miles long, it is fed by over 40 lateral tributaries which rise from the glacial lakelets and marshes along the east crest of the highest Sierras. It furnishes not only water for Los Angeles City, but irrigating waters for the sloping alluvial plains that are made up largely of merged delta fan surfaces. These plains are covered with deep granitic alluvial soils which vary from sands to sandy loams. The valley is extensively cultivated and is particularly adapted to stock raising. The *Honey Lake* region and north to Goose Lake is a plateau region consisting of valleys dotted with sage brush and rugged isolated mountains. The general elevation is 4000 feet, the buttes and local ranges rising from 1000 to 5000 feet higher. The soils are mainly residual from the lava which weathers into a light but very fertile soil. There are large areas of cultivated land and still larger stretches of barren lava table lands. The *Mojave Valley* district lies to the north of Mt. San Bernardino. The Mojave River is 100 miles long but preserves its life by concealment, creeping through the gravel and betraying its existence only where cross ledges of rock force it to the surface. It drains an area of 1470 square miles, of which 251 are mountains, 219 foothills and 1000 of arid plains and barren buttes. The valley is devoted to alfalfa and farm produce with here and there fine orchards. The soils are sands and sandy loams, generally micaceous and fairly free from alkali. Antelope, Rock Creek and several other subdistricts might be described which are within the boundaries of the Basin, but receive irrigation waters from the great ranges which they border, their soils being rich sandy loams and sands, with here and there some admixture of the clays.

THE CASCADE PROVINCE. The Cascade Mountains form the southern extension of the great lava covered range of Oregon, and includes the region from Mt. Shasta east to the Great Basin, and south to the Sierra Nevada, just touching the extreme north end of the Great Valley. Mt. Shasta, 14,380 feet elevation, is the culminating peak, the region descending eastward to the plateau of the lakes 4000 feet, and southward to the head of the Great Valley, which is about 800 feet above the sea level. Nearly all of its drainage enters the north end of the Great Valley and runs into the Sacramento River, the tributaries and their watersheds being the Pitt River, 4597 square miles; head of Sacramento River, 538; McCloud River, 678; Battle Creek, 337; Antelope Creek, 129; Mill Creek, 154, and Ditch Creek, 192 square miles. The region is heavily timbered and the agricultural portions small.

THE KLAMATH PROVINCE. The Klamath mountains extend from Oregon south into this State over 200 miles. The name includes the local ranges known as the McCloud, Trinity, Bully Choop, Scott, Salmon and other mountains, whose geologic and soil histories are essentially the same throughout. The province is covered by rugged ranges from 5000 to 10,000 feet high, and is accessible only by wagon roads. It is given up mainly to mining, timber, cattle and sheep, with some farms in the broader valleys. The terraced stream valleys are often more than 2000 feet deep and range in form from V-shaped canyons to broad, flat valleys. The rainfall in the eastern portion is 40 inches, but west of the divides increases to 60, and near the coast reaches 70 inches. Nearly all of the drainage goes to the ocean from the Klamath River with its 2468 square miles of drainage area, Scott's River, 841; Trinity, 930; Smith, 691, and Redwood Creek, 285 square miles.

CHAPTER VI.

CALIFORNIA GEOLOGIC PROVINCES

The geologic age of any soil, or the age of the rocks from which it was derived is only of general interest and not always of specific value in determining the adaptability of the soil to crops. The classification of soils according to the geologic history, however, give us clearer ideas of the origin and therefore the character of soils in general, and it is worth while to glance at the geologic history of the provinces.

SIERRA NEVADA PROVINCE. We speak of the hills and mountains as everlasting and use them as symbols of permanency. Geology, however, teaches us that they, like everything else in the universe, have their birth, youth, maturity, old age and death, and that their death, like that of everything else, means not annihilation but change of form and another and a new existence, and that ever in the line of advancement and progression in the scheme of existence.

The great Sierra Nevadas of today are young mountains in rugged and vigorous condition, doing their work as sky-line guardians of the fertility of the plains below and their teeming forms of life. They catch the moisture rising from the ocean and condense it into rains and snow and store it among their crags to irrigate the soils miles away. They give each rivulet and each stream its load of material to carry down and build up new soils and renew old ones. They were born during the later part of the Jurassic time, but not to their present magnitude. By the end of the Cretaceous they had been worn down almost to peneplain. In the Eocene and Miocene they were cut and carved by rivers having wholly different courses from those that exist today, many of them leaving their gold-bearing gravels to pay for the opening of the state to the farmer and fruit raiser of today. Still later came the final uplift, when the towering crests were covered with glaciers, the great soil mills of the earth, whose waters fed lakes in basin and valley, where loads of sediment were deposited by hard-working streams busy in preparing lake, or lacustrine, soils for the coming of mankind. The great

mass of the Sierras is composed of granitic rocks, flanked in the northern and central portion by long parallel belts of Jurassic and Triassic slates and shales, and Mississippian limestones, and flanked along the foothills at the edge of the Great Valley by beds of Miocene and Pliocene sandstones, marls, limestones, tuffs, clays, and shales; the whole spotted here and there with lavas ancient and recent.

The geologic history of the Sierra Madre, San Bernardino and San Jacinto ranges and the rocks forming them is essentially the same as that of the Sierra Nevada and they are included in that province.

GREAT VALLEY PROVINCE. In its earlier geologic history the Great Valley has not always drained into the ocean by way of San Francisco Bay. There is geologic evidence that it has at other times emptied into the ocean at points farther south, and it was not until later that faulting broke the mountains and formed the Golden Gate. In earlier geologic times the valley was submerged by the waters of a great inland lake, or by an arm of the sea. The gradation of the Sierras laid down a vast quantity of materials filling the valley to great depths. The great rivers of the Sierras brought down sands worn from granite, quartz, porphyry and lava and emptied them into the lake. These were carried by the currents and distributed along the shores and over the bed of the lake and deposited as stratified clays, sand and gravel, or as beaches composed of gravel mixed with finer material. Still later the land was elevated and the more or less consolidated accumulations were exposed to new weathering and erosion. Great quantities of material were removed, leaving the greater thickness of the beds along the edges and more elevated slopes of the valley, often as rounded foothills of ferruginous and calcareous conglomerates, partially weathered shales, interstratified with sand and silt. The subsequent weathering of this material has given rise to residual soils along the foothills.

Some of this residual material, through the action of gravity, or from heavy rains, has slid, or rolled, or been washed short distances and accumulated as colluvial soils on the lower slopes. More erosion has carried the finer portions of the deposits over the valley slopes and along the flood plains of the larger streams, forming alluvial soil.

The intermediate upland plains receive loams, clays, and clay

adobes. The flood plains sandy and silty materials, and the river bottoms and lowest plains receive deep fine alluvial sands, silts, and clays. Naturally soils so formed shade into each other, the boundaries being obliterated by recent modifying agencies of wind and water. Each soil is subjected to considerable local variation in color, texture, and crop value according to the local conditions of wind, rainfall, and material on or away from the land, or washed on to it from adjacent soils.

COAST RANGE PROVINCE. The Coast Ranges consist of mountains that are roughly parallel anticlines, their corresponding synclines forming the valleys. The formations north of San Francisco consist mainly of Jurassic rocks in the interior, and Cretaceous rocks next to the coast. South of San Francisco the ranges are mainly Miocene and Pliocene formations with some Cretaceous and Jurassic. The rocks are mainly shales and sandstones with occasional igneous rocks. Residual soils were first formed from these rocks, and are found on the ranges and higher foothills. This was followed by the creeping of colluvial soils down the slopes, and the washing of alluvial soils over the flats. The shales have imparted a somewhat heavy character to the soils through weathering into silts and clays, but the sandstones have relieved and lightened the soils by the sands washed or blown into them.

GREAT BASIN PROVINCE. This great arid region is a closed basin into which the rainfall drains to the lowest depressions and then evaporates. This action leaches the soils and the minerals dissolved out accumulate in the low depressions, forming deposits of soda, salt, borax, etc. The basin is occupied by many mountain ranges, most of which dip westerly. The type of structure is that of the faulted monocline, or block tilted up at one edge or corner. Many of the ranges are formed of pre-Cambrian granites and schists, and show along their flanks exposures of Cambrian, Ordovician, Silurian, and Devonian rocks. Most of the valleys between the ranges are covered with eolian sands. Extensive areas are covered with Tertiary or later lavas. All these rocks give rise to vast areas of arid, rough, stony soils not suited to agriculture and therefore not mapped or classified by the U. S. Bureau of Soils. Certain areas close to the flanks of the main range, such as the Owens Valley, Antelope Valley, Mojave Valley, and the Imperial region are exceptions, as they

receive more rainfall, and water can be brought from the mountains and rivers for irrigation.

The Great Basin is, however, of as great importance to the state in general as is a good furnace to the equipment of a palace. It is the place where the atmosphere is quickly heated in the daytime and rising tends to create a vacuum towards which the moisture-laden winds of the ocean flow, giving the rains in the mountains, and the cool invigorating breezes to the coast lands and to the Great Valley. The periodic changes of climate in the ages past are recorded in the Great Basin in the rise and fall of former great lakes, such as the lakes known to the geologists as Pa Ute Lake, Lake Lahontan, and others. Their terraces still exist, showing various periods of increasing and decreasing rainfall and evaporation, each of which meant soil building under varying conditions.

CASCADE PROVINCE. The Cascade mountains form the southern extension of the great lava covered range of Oregon that comes south a short distance into this state. This range in Oregon shows the underlying core of granites and slates of the Jurassic time, and the heavy limestones of the Carboniferous, similar to the Sierra Province. In California, however, lavas and other effusives of the Tertiary and later times cover most of the country within this province. The residual and colluvial soils from the lava are rich in plant food, and where water can be obtained produce crops in abundance.

KLAMATH PROVINCE. This region is made up of formations older than those of the Sierras. Rocks of the Cambrian, Devonian, and Mississippian and other periods of the Paleozoic age have been identified, flanked on the south by the Comanchean and Jurassic. It was reduced in Cretaceous time to a peneplain, and is now a high mountain plateau rejuvenated by late uplifts, the rivers deepening and widening their channels. It shows the effect of glacial action and lava flows. The soils of the valleys are sands and gravels mixed with silts and clays.

PART III

CHAPTER VII.

SOIL CLASSIFICATION NECESSARY

COMMON NAMES ARE MISLEADING

It has been a recognized fact since the dawn of history that soils differ, and many names have been given them. Many of the names in common use have a local value only and are misleading when used away from their home locality. Most of them should be used simply as descriptive adjectives, as they are useless as names for scientific comparison and correlation of soils. A single soil may have several local names in the same state, and the common name is often given totally different soils in different states. This confusion in names often means loss of time and money, and sore disappointment to new settlers. A large number of common names are mere nicknames, quite appropriate in the region where they originate, but wholly misleading and mischievous when transplanted to regions having different climates, different geologic formations, and different local conditions. A little examination into soil names in common use will show the necessity of having standard methods for classifying, comparing, and naming soils, such as that adopted by the U. S. Bureau of Soils. For example, this bureau has named a soil in Ohio, the "Miami Clay Loam," having a definite origin, definite physical characters, and definitely adapted to certain crops; yet this soil is locally known in various parts of Ohio as *Sugar Tree Soil, Clay Upland Soil, Limestone Soil, White Clay Soil, Red Clay Soil* and *Beach Land Soil.* In Texas clays are variously known as *Ashy Flats Soil, Black Waxy Land Soil, Boggy Land Soil, Highland Soil,* and *Tight Soil.* Peat, muck and swamp soils are often called *Acid Soils* on account of the humic acid they concontain. No sharp line can be drawn in many cases between alluvial soils and those made by the wind, yet the term *Aeolian,* or *Eolian,* is convenient when speaking of the origin of many soils, but is a misnomer for other soils that are really largely alluvial in

origin. The soils of the most productive portions of California are soils of the arid region, but are not *Arid Soils.* This term properly used applies to the soils formed where the rainfall is small in distinction to soils formed where the rainfall is large, and has nothing to do with their fertility, or adaptation to crops. A common name in Maryland and elsewhere for any non-productive soil is *The Barrens,* but in Alabama it means only the lands where there is scant timber. The character of trees or vegetation grown often gives the name as the *Beech Land Soil,* which applies, however, only to clay land in Ohio. *Beeswax* and *Canebrake* soils are found in Alabama, while *Chocolate Soil* comes from South Carolina. The *Blue Grass Soil* of Kentucky is famous, but many soils that are not from limestone are adapted to this grass. Such names as *Black Soil, Black Land, Black Prairie* may mean the silt loams of Illinois and Wisconsin, the loams of Ohio, the clay loams of Virginia, or the dark clays of Mississippi or Texas. The black jack oak trees give the name *Black Jack Soil to* clays, clay loams, and gravel in the Carolinas; but in Georgia soils growing the oaks as well as the mayhaw are known as *Black Gum Soil.* The clay loams of Michigan are known as *Black Walnut Soil,* while the clay loams of Texas are called *Black Post Oak Soil.* The use of the name *Black Ash Soil* is even more diverse. *Baybush Pocoson,* or *Pocoson,* means a swamp land that is not subject to overflow, in North Carolina, and *Brier Pocoson,* or Gallberry Land, is named in Maryland for the vegetation without reference to the flooding. A famous cotton soil of the South is known as *Buckshot Soil* because it crushes into grains, or buckshot, when dry. In North Carolina they have the black spongy *Buckleberry Soil* of the swamps; in Louisiana sandy soils named for the *Bullnettle* or *Chinquapin.*

A disintegrated rotten limestone combined with abundant humus gives the well-known *Canebrake Soil* of the South. The soil resting on bedrock is often called *Capsoil,* a term that lacks the definiteness of the better name—residual soil. The *Chalk Soils* of England and France that originate from the chalk deposits are well named, but many whitish colored soils receive this name that have no chalk in them. The name *Cold Soil* might suggest that the land was retentive of water late in the spring or was badly located on the north side of a mountain, but would not point out the physical character of the soil as a name should do. The crayfish live in soils where they do not have to go deep

for water; hence we find the name *Crawfish Soil* in several states. *Cedar Soil, Chestnut Soil,* and *Cypress Soil* are names whose origin is obvious. The name *Cumulose Soil* was used for some time but has given place to other names in late years. It was applied to accumulations in *situ* for years or centuries of organic and inorganic material in lakes that had no outlet: to the peat, muck, or swamp soils in part at the head of valleys, in deserted river beds, in river deltas and other partially drained areas. Some soils in South Carolina are called *Deadland Soil,* not because the clay lacks in fertility but because it is sticky and hard to cultivate, that is not lively and not to be moved easily. In the arid regions of the West, the *Dust Soil* rises in the air at the merest puff of wind. The coarse detrital material caused by a flood, such as a cloudburst in the arid regions, is called by some *Dilluvial Soil.* An inappropriate name proposed for sedimentary soils was *Endogenous Soil,* as objectionable as the term *Exogenous Soil* which was proposed for transported soils. *Fine Soil* is a term that should be used only with reference to the texture of the soil, or as an adjective of praise, but not as a soil name. The name *Flat Woods Soil* is used for poorly drained clays in Mississippi; while similar similar soils are known in West Virginia as *First Bottom Land Soil,* and as *Flat Pine Wood Soil* in Florida. In the cotton states where the surface of the lands has been eroded, exposing the unproductive subsoil, it is called *Galled Soil.* The sands of California, the loams of Illinois, and the mucks of the South, are all good *Garden Soil.* The residue of coarse swamp grass, sedge, flag, etc., is called *Grass Peat Soil* in some states. A general term for deposits from melting ice sheets is *Glacial Soil,* which is more variable in character than alluvial soils and in general is nearly as productive. The glacial and boulder clay contain a variety of minerals finely ground and intimately mixed, and are very fertile when they contain enough sand and gravel to be pervious to water and workable. The *Glade Lands,* or *Conowingo Barrens* of Maryland are very different from the *Glade Soil* or muck of Kentucky. Many soils are derived from granitic rocks, but the name *Granite Soil* is not more specific; it may be a sand, loam, sandy loam, or something else. In Alabama some clays are called *Gray Land, Gray Prairie,* or *Gray Soil;* but these names mean a sandy loam in Virginia, a silt loam in South Carolina and Tennessee, a loam in Texas, and a sandy loam in Georgia.

The name *Gumbo* is well known from the Dakotas to the Gulf of Mexico and west to the Pacific. It is not confined to the clays but is loosely applied to any tough and very plastic soil that is very sticky when wet and hard when dry. The name *White Gum Slash Soil* and *Glady Soil* are Texan local names. A rough sandy loam in Georgia is known as *Rough Pimply Soil,* and a peaty clay in Mississippi is called *Heavy Bottom Soil.* The name *Hemlock Soil* means a loam in New York and a sand in Michigan. The name *Hog Wallow Soil* indicates hummocks in California, hollows in Texas, and land where the "hog-haw" trees grow in Louisiana. Soils which are rich in humus are generally in better physical condition than those low in this organic matter, as humus is somewhat plastic and tends to hold the soil in a more loose condition, but *Humus Soil* is a misnomer. The micaceous loams of Alabama are called *Isinglass Soil.* The origin of the name *Ivyland Soil* in North Carolina and the *Jack Pine Soil* in Michigan are obvious. Soils formed where lakes have dried up are geologically known as lacustrine or lake soils, but the term *Lake Front Soil* applies only to the lands along Lake Erie in Pennsylvania. The name *Laterite* (brick earth) is commonly applied to any red soil, but its use should be restricted to red, iron-stained, residual clay soil formed by the weathering of volcanic rocks.

Limestone Soil and *Limestone Land* indicate the origin of the soil, which may be any one of several kinds. One term that has been so loosely applied as to rob it of its significance both as a geologic term and as a soil name is *Loess.* It is even misused as synonymous with adobe. Its origin whether as eolian or sedimentary, or both, is still a matter of controversy. Any soil too wet to give a solid footing is known as *Looseland Soil* in Delaware. The term *Marine Soils* is general and applied to soils that consist of stratified gravels, sands, silts, and clays deposited originally in offshore water, and later raised above the sea level, where they have not consolidated into rock and weather rapidly. Such names as *Marly Peat, Medium Peat, Peaty Loam,* and *Moss Peat,* can only be used locally. The *Mesquite Soil* is Nevada is sand, and that of the mesquite flats or prairies of Texas is a clay loam. The moors of Scotland give us the name *Moor Earth.* A general term loosely applied is *Mountain Soil.* The rocks high up in the mountains often consist of granites, gneiss, schists, slates, limestones, and igneous rocks. These give rise to stony soils, or rough broken areas best suited to forestry, but the soils themselves may

vary from coarse gravels and sands to clays. The *Mulatto Soil* or *Mottled Soil* of the South takes its name from its yellow color, and is wholly different from the *Niggerhead* (boulders) lands of New England. Many varieties of soils contain large amounts of lime and are locally known as *Marl Soil.* Wherever oak trees grow the term *Oak Soil* comes into use. The term *Peaty Alkali Soil* is one that would puzzle most field analysts to identify. The *Piney Wood Land* of Texas is a clay soil; the *Pine Barrens* of Maryland is a sand; the *Piney Woods* of Alabama a loam; and the *Pine Flats* of Arkansas a clay loam. The *Post Oak Flats, Post Oak Prairie,* and the *Post Oak Swags* from Virginia vary from heavy clays to sandy loams. *Pipeclay Soil* is a local name used from Maryland to California. Any treeless soil of the middle west may be called *Prairie Soil* without reference to its real character.

The name *Redlands* means a clay in Alabama, Virginia and Texas; a loam in Missouri; and a sandy loam in Georgia and Wyoming. The *Red Clay* of Delaware is a silt loam technically known as the "Norfolk Silt Loam," and the color is generally yellow instead of red. In Virginia *Red Clay Soil* is generally synonymous with *Mulatto Soil.* The dark clayey cotton soil of India is known as *Regur,* a name that has lately been transplanted to this country along with the Egyptian cotton. Flooded lands along the sea coast are often called *Salt Marsh Soils.* All kinds of soils have been called *Scrub Oak Soil.* Where soils are composed of materials that have not been subjected to any appreciable transportation they are often called *Sedentary Soils,* and by some are divided into residual soils when they consist of residue left by rock decomposition, and cumulose when they result from the slow accumulation and decay of plant remains. Some loams in Pennsylvania contain fragments of shale of the size and shape of shoepegs and the soil is locally known as *Shoepeg Soil.* The common use of the names *Silt Soils* and *Sand Soils* means rock powders produced by the mechanical pulverization of various minerals, of which quartz is the most common. If the fragments are not worn or rounded the sand is said to be sharp. Compare this loose use of these names with the precise definition given on another page. Any soil that is rich in available plant food is a *Strong Soil;* any tenacious heavy soil is a *Stiff Soil.*

The most mischievous and misleading name is *Sterile Soil,* applied to any soil that does not produce vegetation of some kind

naturally, such as the lands of the deserts, sandunes, lavas, etc. It is nearly always a misnomer as the sterility is not due to the inherent character of the soil, but to local conditions, such as climate, lack of irrigating water, etc. In the humid regions many soils that are said to be *Wornout Soil,* and sterile, are simply soils that are sick, tired, abused or poisoned by toxins, and recover all their vigor when restored to proper physical condition. Swampy soils may be called locally *Tamarack Soil,* or for any other tree that grows in them, or *Tidal Soil* if near the coast where high tides submerge them. Sandy soils of glacial origin are often called *Till;* while beds of volcanic ash are called *Tuff* or *Tuff Soil,* but are light soils and never tough soils. Any soils that water, ice, or wind have brought from higher levels and deposited over lower lands are *Transported Soils.* Any soil containing decomposed organic matter in an advanced stage of decomposition, making it a rich soil for growing vegetables, may be called locally *Vegetable Soil, Vegetable Muck,* or *Vegetable Loam.* The English name *Wacke* is applied to a dark compact clayey soil resulting from the decomposition in place of basaltic rocks. Any dark colored or sandy soil that absorbs and retains heat readily is a *Warm Soil.* Any soil that is easily washed away by rains is a *Wash Soil.* The plastic clays of Virginia and Texas are known as *Wax Soil* or *Tallow Soil. White Oak Soils* are loam or silt soils in Illinois and Maryland, and clay in Missouri. A silt loam in the South is often called *White Land Soil.* It shows a groping towards identification and classification when the vernacular contains such terms as *Beeswax Soil* for sticky clay in North Carolina; *Bugle Land Soil* where the pitcher plant grows in Georgia; *Chaffy Soil* or sands that the winds blow like chaff in Delaware; *Spouty Soil* that squirts up water when stepped upon in Pennsylvania; *Yellow Prairie Soil* for the treeless clay loams of Alabama; and *Tight Soil* that is hard to turn over with a plow in Texas.

California has many local soil names which are noted with the technical names in the latter part of the book. Thus we have *Dry Bog Land* as a local name for the Portersville clay adobe around Portersville; *Dry Bog Adobe* for the Portersville clay loam adobe; *Dry Bog Soil* for the Stockton clay loam adobe in the Fresno region; *Foothill Soil* for the Placentia loam adobe around Santa Ana; and *Hogwallow Land* for the Dunnigan clay near Woodland. The Santa Cruz sandy loam is locally known

as *Redwood Soil,* where the redwoods (*sequoia sempervirens*) grow. The Sacramento clay is known as *Tule Land* near Marysville; the Fresno sandy loam of the San Joaquin Valley is often called *White Ash Land* from its color and not for trees; and the same name is given locally to the Fresno fine sandy loam; the Feather silt loam is known as *Black Land* near Marysville. *Wild-goose Land* is a nickname for the lower, poorly drained alkali land, unproductive on account of alkali, occupying spots in the Colusa area. The term *White Alkali Soil* is common for lands where the soda salts are largely sulphates, and *Black Alkali Soil* where the soda salts are carbonates.

PART IV

CHAPTER VIII

SOIL PARTICLES

The soils of California include those of the coast, of the coastal and interior mountain ranges, foothills and valleys. The soils of certain type areas in each province have been classified by the U. S. Bureau of Soils, Washington, D. C., and divided into a number of series, varying in field characteristics, topography, origin or mode of formation, and agricultural importance. They range from the residual and colluvial soils of the mountain sides, foot slopes, and foothills, to deep and extensive flood plains and delta sediments, and ancient and modern marine and lacustrine deposits. While some of the series are confined to a single coastal or interior mountain range or valley, others are of wider range and extend over large areas in various parts of the state. The value of these soils and their adaptation to crops is largely dependent upon the possibilities of irrigation and upon local conditions of rainfall and temperature, all of which are to a great extent dependent upon the latitude and upon topography. They range in agricultural importance from those devoted only to extensive grain farming to the most valuable and intensively cultivated lands devoted to citrus fruits, vines, and special crops such as dates, cotton and rice.

In the present struggle for supremacy in commerce the importance of accurate knowledge of agricultural conditions is becoming daily more evident. It is important that the men who control land and who are responible for its future value should have at least a fundamental knowledge of the composition of the common soils to furnish a foundation of facts upon which to build a knowledge of agriculture. A ready working knowledge sufficient for everyday use lies at the basis of success in every industry and profession. The classification used here is taken from the work of the U. S. Bureau of Soils.

ALL SOILS CONTAIN THE SAME MINERALS. One of the most important facts established in recent years is that all

the common minerals are distributed through nearly all the soils, and that normal soils in the most diverse regions are remarkably similar in this respect, all the important soil minerals being present in variable quantities. This fact has revolutionized the study of soils and their treatment by the land owner.

THE NEW THEORY. The theory upon which the United States Bureau of Soils works in their classification and correlation of soils is that *practically ALL SOILS contain sufficient plant food for good crop yield, and that this supply is indefinitely maintained. That the productiveness of a soil depends even more upon its PHYSICAL characteristics than on its chemical composition. That every soil is intended to grow certain definite crops, according to climate and local conditions, and that success largely depends upon finding the proper crop for each soil.*

SOIL PARTICLES. The basic material of the soil is an aggregation of mineral particles ranging from two millimeters in diameter to particles so small that they tax the power of the best microscopes. The different sizes of these particles and the different properties of the different sizes affect the texture, water-bearing capacity, aeration, and other properties of the soil. The minerals themselves are only slightly soluble, but have in the aggregate absorptive capacity in a high degree. This provides a dilute nutritive solution, or mineral soup, of sufficient strength for the needs of the plants. It is evident therefore that the *physical analysis of the soils is far more important than the chemical or mineralogical analysis.* The modern study of the soil is based in fact largely upon the physical structure of the soil, and upon the soil solution.

SIZE OF THE SOIL PARTICLES. The study of the physical character of the soil begins with the particles that compose it. If we consider each particle in a pure soil to be a sphere, then the number of particles in a gram of pure soil may be calculated, the result being as follows:

		Number of Particles
Fine gravel	2. to 1mm	252
Coarse sand	1. to 0.5mm	1,723
Medium sand	0.5 to 0.25mm	13,500
Fine sand	0.25 to 0.1mm	132,600
Very fine sand	0.1 to 0.05mm	1,678,000
Silt	0.05 to 0.005mm	65,100,000
Clay	0.005 to 0.000mm	45,000,000,000

Since normal soils are a mixture of gravel, medium, fine and very fine sands, silt and clay, the number of particles in the soil of

a particular class will depend upon the number of particles present of the above kinds. The approximate number of soil particles present in one gram of soil has been calculated as follows:

	Particles.
Sandy loam contains	6,485,000,000
Fine sand loam	6,902,000,000
Silt loam	9,639,000,000
Clay loam	16,371,000,000
Clay	19,525,000,000

The importance of these millions of particles in any mass of soil lies in their relation to the surface area of each particle. These grains are not in actual contact but separated from each other by thin films of moisture, or in extremely dry soil by actual air space. These spaces between the particles will differ *in size and shape* according to the size and shape of the soil grains.

SURFACE AREA OF THE PARTICLES. The surface of the particles holds the moisture, known as film water. The greater the surface area of the particle the greater the amount of water they hold in the films, or the greater amount of mineral soup present for the plant hair rootlets to feed upon. This increases also the *rate* of chemical solution, increasing the amount of available plant food. A rock three feet cube exposes 54 square feet of surface; divided into one-foot cubes, the surface area is increased to 162 square feet; if broken into one-inch cubes it presents nearly 2000 square feet to erosion and decay; if reduced to bits one-twelfth of an inch cube, the square feet of surface is increased to about 20,000 square feet, or nearly one-half an acre in area. When we remember that in soil analysis in the laboratory, the soil particles are actually separated and classified into six fractions of a millameter, ranging from 1. to 0.005 in diameter, and the percentage of each size obtained, it is evident that the necessary information has been gained as to its value as a feeding ground for crops.

The immense area exposed to the hair-like feeding roots of plants by soils is shown in the following table which gives the internal surface area of field soils in square feet. A cubic foot of

	Square Feet
Coarse sand contains a surface area of	40,500
Medium sand	44,500
Sandy loam	66,600
Fine sandy loam	68,000
Silt loam	104,000
Clay loam	136,500
Clay	142,000

That is, the internal surface of the soil particles on a cubic foot

of clay represent a film surface of nearly three and a quarter acres in area, or in other words one pound of coarse sand would have about 400 square feet of surface, to 2000 square feet in the case of clay.

SOIL SPACE. The space between the particles is also of great importance in determining the circulation of water in the soil and its capacity for retaining capillary water in the right proportion for plant growth. This depends upon how the soil particles are arranged independent of their size. The physical properties of the soil depend upon this more than upon the chemical composition. The physical properties in turn have a fundamental bearing upon the chemical and biologic properties of the soil. The simplest arrangement would be that of spheres touching each other; but such could be arranged in columnar order, touching each other at four points, or in oblique order, each touching one another at six points. If there are spheres of different sizes the small ones would rest in the spaces between the larger ones so that the total voids or pore space would be greatly reduced. This could be continued until the mass was practically solid. Soil particles are, however, irregular in shape and uneven in size, giving each soil an individuality in character.

TEXTURE. The size of the mineral particles determines the soil texture, which influences alike the relation of moisture and the chemical changes that take place through oxidation, especially of the organic bodies in the soil. The texture determines to a large extent the relative capacity of the soils to hold water. Under equal conditions of depth and exposure coarse grained soils hold less moisture and more air than fine grained soils, so that as a whole they contain less soil solution, and consequently less nutrient material available for the plants. They have generally a lower absorptive capacity and permit more rapid oxidation. Another important factor is the structure or the arrangement of the mineral matter. In some soils the mineral portions have a granulated arrangement of flocculated masses, making the soil loose and porous; in others the grains exist in a compact form, making the soil hard and compact. The adobe soils, for example, are hard and compact, while sands are open and porous. Another factor is the amount of humus or organic matter present, as it influences not only the productive capacity of the soil but also its adaptation to crops. The following table illustrates the effect of texture:

Coarse sand	containing	4.8%	of clay	holds	1.6%	capillary	moisture
Medium sandy loam	"	7.3%	"	"	7.0%	"	"
Fine sandy loam	"	12.6%	"	"	11.8%	"	"
Silt	"	10.6%	"	"	12.9%	"	"
Silt loam	"	17.7%	"	"	26.9%	"	"
Clay loam	"	26.6%	"	"	32.4%	"	"
Clay	"	59.8%	"	"	46.5%	"	"

POROSITY. There is always some unoccupied or pore space or voids among the particles in all soils. If the particles are fine the voids are small. If the particles are large the pore spaces are large. A clay has more total pore space than sand, although the individual spaces are much smaller in the clay. This relation between texture and pore space is shown by the following table:

	Percent Pore Space by Volume
Clean sand contains	33.50
Coarse sand	40.00
Medium sand	41.80
Fine sand	44.10
Sandy loam	51.00
Fine sandy loam	50.00
Silt loam	53.00
Clay	54.00
Adobe	56.00

A porous soil permits a freer circulation of the gases. The porosity of a soil depends upon (1) the state of divisibility, (2) upon the natural arrangement of the particles, and (3) upon the voids, their size and arrangement.

SOLUBILITY OF THE SOIL MINERALS. The common soil minerals mentioned in Part I are very slightly soluble, about as much so as ordinary glass; but in the finely divided state in which they exist in the soil, an enormous surface is presented upon which the film waters act, forming a soil solution which contains the necessary amount of the mineral plant food elements. Twenty-five parts of potash and ten parts of phosphoric acid per million of solution is ample for the needs of the plants; and the soil solution is said to be saturated when it contains these amounts.

The degree of solubility of each mineral in the water in connection with the mixture of so many kinds of minerals as are found in the soils makes *the concentration and composition of the soil solution nearly the same for all soils.* With 1,000,000 pounds of water in contact with 5,000,000 pounds of soil the solution will contain 25 pounds of dissolved potash, although the amount of potash in the soil may vary from 30,000 pounds in one soil to

120,000 in another. As the 25 pounds of potash is gradually removed from the film water by plants, more goes into solution, so that no sensible change in concentration takes place in the film water solution.

THE SOIL SOLUTION. The water in the soil absorbs gases and takes up soluble mineral, animal, and vegetable matter from the heterogenous mixture called the soil. The component parts of the soil consist of mineral debris from rock decomposition, organic matter from the fermentation and decomposition of former animal and plant tissue, carbon dioxide and other gases from the air, and the products of the activities of myriads of bacteria, fungi, and enzymes. It is from this complex solution that the plants, through their hair roots, draw *all the material* from the soil that is involved in their growth, except that absorbed from the atmosphere. It is well to remember here that after all only about ten per cent of any vegetable growth comes from the soil and that the remaining ninety per cent comes from the atmosphere. Burn a dried plant and the ash or mineral portion is largely from the soil; the carbon, hydrogen and oxygen that made up the bulk of the plant came from the atmosphere. The study of the soil solution and its relation to the soil and to plant growth is of the highest importance, but belongs to agricultural chemistry and to biology and not to the origin and classification of the soils. So far as the mineral portion of the soil is concerned the concentration of the minerals dissolved in the soil solution under normal conditions *is sufficient to support ordinary plant crops.* Changes in the concentration and proportion of the minerals dissolved produce a rapid or a slower growth, and a greater or less total growth, and differences in the character of the growth, such as the tops growing faster than the roots, or the reverse. The soil solution affects the physical character of the soil, for most dissolved substances affect the granulation or flocculation of the soil particles. Magnesium, sodium and potassium chlorides and sodium nitrate make the soil moist in dry weather by increasing the surface tension of the soil solution. When this tension is increased, water is drawn towards this point; hence fertilizers may assist in drawing water up in the soil. Oily substances do not go into solution but spread in a film decreasing the surface tension and diminishing capillarity. Some organic matters in solution act the same as oil.

PHYSICAL ABSORPTION, OR ADSORPTION. Soil particles attract and hold materials such as gases and dissolved salts upon their surfaces. This is called absorption or adsorption and is not to be confounded with chemical absorption. It varies with the extent of surface exposed, and is greater in the fine textured soils. This is an important factor in the retention of fertilizers. This important property of the soils also tends to control the concentration of the soil solution and to prevent undue waste of material. This adsorptive power varies greatly in different soils and with different minerals, and varies for different substances and parts of substances; thus it is stronger for potash than it is for chlorine, and will absorb potash from chloride of potash. It is an important factor in regulating the concentration of the soil solution. This action also purifies the waters passing through the soil. If it were not for this property, wells would soon become unwholesome from seepage. Soils absorb the gaseous products of dead bodies and the products of the decomposition of animal and vegetable matter. They withdraw and retain certain minerals held in solution, as the sands along the seashore absorb the saline matter so that quite pure water may be obtained by digging in the sand some distance back from the water's edge. Soils absorb the soluble minerals from fertilizers. If a soluble sulphate, chloride, or nitrate of an alkali comes in contact with soil a *part of the base* and *none of the acid* is withdrawn. Generally, however, there is some other base in the soil that may join the liberated acid forming new products, otherwise the acid leaches out. Soils also absorb dissolved substances by mechanical inclusion or trapping (imbibation) as a sponge; or a mineral such as lime or ferric oxide may absorb phosphoric acid, forming a new compound, as lime or iron phosphate. Soils absorb potassium more readily than sodium, magnesia than lime, and ammonia more than any of these bases. More potassium is absorbed from the sulphate than from the chloride of potassium. Clays especially absorb potassium. Oxides of iron absorb potassium and ammonia. Soils remove both the base and acids of soluble phosphates and silicates. The nitrogen of insoluble organic bodies which nitrify slowly is absorbed and retained; but nitrate of soda is an exception and is not absorbed, and is readily washed out of the soil. The absorptive power depends upon the relative amounts of surface exposed which depends upon the size of the particles, upon the kind of surface acting, upon the concentration of the solutions, upon the

time of contact, and upon the temperature. The finer the particles the greater the surface and the greater the absorptive power. The fine soils thus hold the plant food too closely to allow rapid loss through drainage. Heavy soils containing hydrated ferric oxide absorb bases more readily than the light soils. Soils rich in humus are better absorbers than soils not so rich. The absorptive power of soils is many times greater than it is ever called upon to exert in sustaining field crops, or in fixing applied fertilizers. An acre of soil nine inches deep could absorb nine and a quarter tons of phosphoric acid, while 500 pounds is the maximum for field crops. A soil can absorb twenty-seven times as much potash as is called for, and thirty-two times as much ammonia. During dry weather plants require a soil that is absorptive and retentive of water. The water absorbed by the roots passes into plant circulation and must be evaporated by the leaves.

	Pounds of water
1 acre of wheat exhales	409,832
Clover	1,096,234
Sunflowers	12,585,994
Cabbage	5,049,194
Grape vines	730,733
Hops	4,445,021

Cultivation conserves the soil moisture.

CHAPTER IX

SOIL MOISTURE

Soils vary widely in their moisture contents. The supply is determined by precipitation as rain or snow, by underground seepage, and by irrigation. The soil moisture with its dissolved substances forms the nutrient solution for the support of plants; yet water may exist in soils and not be available for nutrition. Soils may contain water in different ways or conditions, each condition exhibiting markedly different physical properties and peculiarities. The water present may be (1) gravitational water, (2) capillary water, (3) hygroscopic water, (4) chemically combined water or water of hydration, and (5) as film water.

GRAVITATIONAL WATER. This is water that is free to move through the soil under the influence of gravity. It is water present in *excess* of the amount which the soil is able to retain and which is free to drain away, and depends upon the maximum capacity of the soil to hold water. This retentive capacity of the soil varies according to the physical properties. Plants suffer much more quickly from drought on sand where the retentive capacity is small, than on clay where the retentive capacity is large, even when the soils are equally wet at the outset. The drainage features of the soil control the amount of gravitational water retained; the amount of excess salts held in solution; and often materially influence the organic constituents, the aeration, and the oxidation of the soil. Artificial drainage gives greater depth to the working soil, warms the soil, admits air, increases the amount of plant food, lengthens the growing season, improves the texture, increases the porosity, and prevents waste through heavy washing.

CAPILLARY WATER is that which is retained in the capillary spaces in spite of gravity, and which is capable of movement under capillary conditions. The capillary capacity of a soil depends upon (1) the texture of the soil, (2) upon the structure, (3) and upon the organic content. The capillary water is the principle source of water and mineral plant food to the plants, and is probably the seat of important chemical and biologic

changes in the soil. The relative amount of capillary water depends upon the texture, the depth of the soil, drainage, and the amount of organic matter present. The best amounts of capillary water, called the *optimum amount*, varies with each soil, ranging from twenty per cent of the weight of dry clay soil to four per cent for some sandy soils.

Capillary movement may take place upward, downward or laterally. After a rain, when the surface of the soil is more moist than that below, capillary action aids gravity and hastens the penetration of the water downward, but as soon as the surface soil becomes the dryer the capillary flow is upward. Where plants are growing the movement is towards the roots from all sides where the soil has more water than in the vicinity of the roots. The rate of the capillary movement varies with the distance the water must be moved and the character of the pore spaces through which the water must move. For fine sands the rate by experiment was 2.37 pounds per square foot per day of 24 hours, and for clay loam was 2.05 pounds. When the soil becomes nearly air dry to any considerable depth the pore space becomes filled with air and this must be expelled before water can enter. In some sandy soils the air spaces are large, the air readily displaced, and the soil easily moistened. In fine soils a moderate shower fills up the surface pores at once and prevents the escape of the soil air, and this prevents the entrance of the water to any depth. Clays especially remain dry below even when the surface is eroded by heavy rains or irrigation. On such soils time must be taken to let the water soak in slowly, gradually displacing the air from the fine pores of the soil.

WATER VAPOR. Even when the soil contains neither gravitational or capillary water the air that fills the pores or voids contains water vapor that is important in plant nourishment.

HYGROSCOPIC WATER, or moisture, is that which condenses from the air on the surface of the soil particles when the soil is allowed to become air-dry. It is found on the surface of the grains and is not capable of movement by gravity or capillarity. The hygroscopic moisture adheres to an air-dried soil and undoubtedly plays an important part in the chemical changes which take place. Under ordinary climatic conditions loams and clays contain as much as four to eight per cent of their weight

of hygroscopic moisture, and soils rich in organic matter contain even more.

Sands have little power of retaining water and all added water flows at once to lower levels and the amount held by capillarity is far less than in soils composed of finer materials such as silt and clay, but they can retain considerable hygroscopic moisture.

WATER OF HYDRATION. This is the water *chemically combined* with the minerals and is of little use directly to the plants in humid climates; but in arid climates certain desert plants avail themselves of water from this source, dehydrating the materials. This water is also known as the *water of crystallization.* Thus, gypsum is sulphate of lime ($CaSO_4$) plus ($2H_2O$) two molecules of water; or in other words, 100 pounds of common land plaster or gypsum is really 79.1 pounds of sulphate of lime and 20.9 pounds of water. When the gypsum is burned the water of crystallization is driven off and "plaster of paris" is left. Other minerals contain water of crystallization, as glauber salts (sulphate of soda), borax, etc.

FILM WATER. This is the most important form in which water exists in soils, yet little attention has been given it until recently. Drop a marble into mercury and it comes out dry. Lift it from water and it carries a film of water over its entire surface due to *the attraction of the marble for water,* or adhesion. The film is thick on account of the attraction of the particles of water for each other, or cohesion.

Soils must be moist or plants will not grow, but this water does not fill the spaces in the soil proper; it sticks to the grains covering them with a thin film while the air fills the spaces between the particles. It clings so closely that it cannot be rubbed off and is not easily driven off except by heats greater than that to which soils are naturally subjected.

The very driest road dust has some film water clinging to it. It is the film water that is the feeding ground of the plants, the mineral soup that nourishes them. The hair-like rootlets, some of them only three-hundredths of an inch in diameter, must come into intimate contact with the film of moisture, without being excluded from the air supply which promotes their growth. The right amount of film moisture and air in the air spaces is the key to success in modern agriculture. The chemistry and physics of

the film moisture is one of the most interesting studies in agricultural chemistry. The Bureau of Soils has discovered that there is a pressure on the surface of a mineral particle moistened with water, acting at an inconceivably small distance from the solid surface, which is estimated as at least 10,000 atmospheres, or 150,000 pounds per square inch, or fifteen times the muzzle pressure of a 12-inch gun. Under this pressure the concentration of the solution is enormously increased in the surface film on the soil particle, and chemical changes and reactions may take place there which are impossible to duplicate in the chemist's laboratory. Each root is at first a slender thread-like object which extends itself through the voids in the soil. When it obtains lodgment on a particle it rapidly increases in size and vigor. From a slender fiber of microscopic size, less than the 1/300 of an inch in diameter, it may increase to a foot or more across. These rootlets spread like an octopus through the soil, feeding on the film waters and soil solution. They are always moving, absorbing and excreting water and dissolved substances, and ever pushing forward. When they die they contribute their organic matter to the soil and their decay leaves channels through the soil facilitating drainage and aeration.

CRITICAL MOISTURE CONTENT. The amount of water available at which the plants are just able to survive is termed the minimum or *critical moisture content;* the highest per cent at which the plant will survive is the *maximum moisture content;* and the intermediate point at which any crop makes its best growth is the *optimum moisture content.* Each of these points, or moisture conditions, is very definite for each soil and each crop. The maximum and minimum points are marked by distinct changes in (1) the cohesion of the soil, (2) in the volume weight of the soil, and (3) in the freedom with which the soil gives up its moisture. Between the maximum and minimum the soil works the best; it does not puddle, gives the desired *granulation,* known as good *tilth,* and the clods are not hard, and the ground is easily pulverized.

The *maximum water capacity* is the total amount of water which can be put into a given volume of soil. It depends upon the total pore space of the soil. The following shows the amount of water present in some soils at the saturation point:

	Percent at Saturation
Dunesand	40.5
Coarse sand	39.5
Fine sandy loam	38.0
Light silt loam	38.0
Clay	54.5
Humus	333.3

A saturated condition of the soil is unfavorable to agriculture, except to the swamp types such as rice and cranberries. The gravitational water must be removed by natural or artificial drainage for other crops to grow, as its presence in the root zone is injurious to most farm crops.

EVAPORATION. The sun is the greatest of all pumps, and the rate of evaporation for any soil is important. It is relatively rapid above the optimum amount of moisture, and very much slower below that point, and to a large extent takes place within the soil instead of from the surface, the vapor coming out through the slow process of diffusion. A dry surface mulch conserves the moisture below by protecting from surface evaporation, as the capillary movement of water in the dry mulch is exceedingly slow. The waters in the lower layers can loose only by being raised to the surface by capillary action. This is the fundamental secret of dry farming. Evaporation is affected also by the attitude of the soil, being greater where the soil is exposed to the direct heat of the sun, and less in shaded places.

WATER TABLE. The point at which water stands in soil is called the *water table*. If it is only two or three feet from the surface there is not enough dry soil for the roots to grow in and they drown. Such soils are said to be shallow. If it is too deep, water does not rise from it by capillary attraction and the plants suffer from drought. The height of the water table depends upon the texture of the soil, the character of the subsoil, the presence or absence of hardpan, natural or artificial drainage, etc. If a well is sunk eighty feet and fills up with water to within fifteen feet of the surface, it means that the ground is full of water to that level. This level is known as the *ground water level, ground water surface, or water table*. During wet weather the water table rises, and in periods of drought it sinks. In lakes, marshes and streams the water table stands at the surface. It is never at rest, rising or falling and moving in slow currents through porous rocks and rapidly in joints and cracks and underground channels. It is the source of springs,

and is important in extending the process of weathering and rock decay below the subsoil and deep into the bedrock. A fluctuating water table permits roots to develop during one season at a certain depth, and then by a rise or fall of the ground water either drowns them or leaves them thirsty. The condition of the water level should always be studied in connection with all soils before planting anything, and the method of irrigating and the amount of water used should be regulated accordingly. In one part of this state when irrigation began, the water table was from seventy to one hundred and fifty feet down; now it is from ten feet to surface level. This shows great waste of water in some manner. All water that passes below the depth of root penetration is not only lost to all good at the point applied but may be a serious menace to land lying lower. Why waste water by soaking the ground when the plants feed upon all moisture except gravitational water?

The ideal way would be to copy nature and irrigate with a spray falling like rain, giving the ground only what it needs for film and capillary water and leaving the needed amount of air in the voids, and protecting the water from evaporation by keeping the surface in good tilth by cultivation, or by mulching. When this is done, then the irrigation waters of the state will be conserved and extended to several times the amount of land they are now used for.

CHAPTER X

VARIOUS DEFINITIONS

Soils become sticky or plastic, when mixed with water, and this property is termed *plasticity*. In general, the finer the soil the greater the plasticity, as in the finer textured clays. Sandy soils possess it to some extent, however, for this material adheres when wet but falls apart on drying, while clay soils become hard on drying. The plasticity of a soil affects its cultivation and drainage.

Some soils expand on wetting and shrink on drying. This is called *checking*. In a clay soil the surface film draws closer about the particles as the water dries out, and moves the particles closer together. As the mass does not move as a whole, cracks or checks are developed. Very pure clay when dried contracts 18.3 per cent of its original volume, sandy clay 6 per cent, and muck 20 per cent. The finer the texture the greater the shrinkage. When large checks or cracks are formed, the roots of plants may be broken, or at least injured, the soil dries out to greater depths than from surface evaporation, and the advance of rootlets is interfered with.

Small particles of soil, according to the moisture conditions, may adhere to a large one, or a number of small particles may adhere toegther in a group. This structure is called *granular*, or *crumb structure*, when the aggregate of particles is not large and readily fall apart. When the group reaches a large size and interferes with cultivation they are called *clods*.

Dissolved salts, such as lime, oxides of iron, and silica, may be drawn to the surface when the soil is moist, and on drying may bind or *cement* the surfaces together, making the fully dried soil much harder than when moist. Some of the red soils of the coastal plains show a tendency to *case harden* at the surface, an action due to the iron compound present. See *hardpan*, described elsewhere.

SOIL ATMOSPHERE. Plants must have air to breathe and need a well-ventilated soil as a rule. The oxygen of the atmosphere penetrates to a great depth, and acts especially upon the

lower oxides of iron, converting them into peroxides and promoting decay. The soil atmosphere contains less oxygen and is considerably richer in carbonic dioxide and nitrogen than the air above the surface. The diffusion of air through soil is slow, and cultivation is necessary with most crops in order to secure more perfect aeration. Unless air freely enters the soil and is frequently changed, or, in other words, unless the soil is well ventilated, nitrification cannot go on. Hence the necessity for plowing, spading, raking, and stirring the soil by the various methods of cultivation. The air drawn into the soil aids the roots in assimilating plant food. Few vegetables or trees tolerate having their roots permanently bathed in water during the growing season, any more than a human being can keep well if his shoes and stockings are constantly wet. A few species of trees like the bald cypress (*Taxodium distichum*) accommodate themselves to permanently wet earth by processes from their roots which bring air to them; but this is living like a diver, who is dependent upon the air tube that connects him with the necessary atmosphere above.

Gravity, cohesion, and other forces tend to bring the soil particles too close together, giving the soil a compactness that is undesirable. Water and air will not penetrate a soil that is packed too close. When a soil is plowed, air is brought into direct contact with particles that had been previously shut away from it. Plowing and other methods of cultivation are chiefly beneficial because of their effect upon soil ventilation. Heavy soils need more cultivation and more thorough cultivation than light soils. The purpose of cultivation is to break up and fine the soil more than it is to keep down the weeds; to admit air into the soil and to form mulches to check the evaporation of the capillary and film waters.

The aeration of the soil and the structure and arrangement of the particles is improved by alternating deep rooted and shallow rooted crops, just as it is improved by alternating deep plowing with shallow ploughing.

SOIL TEMPERATURE. Soils must be warm in order to produce crops. The colder the soil the slower the seeds germinate. Crops differ in this respect, for the temperature favorable for the germination of barley is 70 degrees F., clover 77 to 100, pumpkins and tomatoes 100. Onions, barley, turnips,

parsnips, peas, and potatoes are cool plants and can be planted when the ground is cold; tomatoes, melons, squashes, etc., are hot plants that do not grow until the soil is thoroughly warm.

The sun is the furnace that heats the soil, and this heat is subject to seasonal and hourly variation. The temperature of the soil depends upon (1) the heat supply, (2) upon the specific gravity of the soil, (3) upon the specific heat of the soil, (4) upon the color, (5) upon the attitude or location, as on a north or south slope, (6) upon the conductivity of the soil particles, (7) upon the circulation of the air in the soil, and (8) upon the character of the water content. The specific gravity of the soil affects the temperature, for the larger the mass is in relation to weight, the more heat required to change its temperature; the more dense the soil, the more heat is absorbed by each layer, and the more rapidly the heat is conducted through the mass. The conductivity of the soil for heat depends upon (1) composition, (2) texture, (3) structure, and (4) moisture content. The coarser the structure the greater the conductivity. A compact soil conducts heat more rapidly than a loose one and gives it off more readily. The coarser the soil the warmer it gets and the better it holds the heat; hence gravelly and sandy loams are among the earliest and warmest of soils. A clay, however, warms faster than sand, for the particles lie closer together and the heat passes more readily from particle to particle, and a clay soil loses heat faster than a sand for the same reason. A clay soil holds more water and loses more heat through the larger evaporation; hence sandy soils are warm and clay soils are cold. Draining a soil warms it. Dark soils absorb more heat and are warmer and earlier than a light colored soil. Uneven and ridged soil loses more heat than a smooth level soil. The presence of small stones and pebbles make a soil more porous and warmer; hence gravelly and sandy soils are the warmest and earliest soils. Clay warms faster than sand, but it also loses heat faster. A smooth surface absorbs heat more than a rough or rigid one. The "lay of the land" or *attitude* of the soil has an important influence upon temperature. A northern slope that receives only one third of the sunshine that the same kind of soil receives on a southern slope may be seven to ten degrees cooler in summer than the soil of the southern slope, while the soil with the southern attitude may be from three to five degrees warmer than the same

soil on the level land lower down, the rays of sunshine striking it at right angles while they strike the level land obliquely.

Chemical changes in the soil are hastened by a high temperature and retarded by a low temperature. For example, barn fertilizers lie dormant in the soil through fall and winter and become active under the heat and moisture of the spring. A *lumpy soil* is cold either because of the lack of humus, or through excessive moisture, and its available feeding ground is also greatly reduced. Frozen soil means a complete suspension of chemical and vital action but not of mechanical. Everyone has noticed the "heaving effect" of ice, how fence posts are raised, and stones are lifted by frozen ground through the expansion of water when it freezes. Soils are pulverized, broken, heaved, and improved by freezing. It aids in the decay of the mineral matter and fines the soil.

ELECTRICITY. Weak currents of electricity are effective in plant growth, and are being utilized in intensive cultivation. They stimulate in some cases the activity of bacteria, and promote chemical activity in the soil solution. It is not yet known what effect they have upon the physical condition of the soil.

DESCRIPTIVE TERMS. Common descriptive terms are applied to soils to designate certain definite properties. When one speaks of a soil as fine, coarse, cold, warm, light, or heavy, he should use these words with precision, and as having relation to definite properties of the soil, and not use them carelessly or loosely.

Other things being equal, the *finer* the particles of the soil the richer it is, because it contains more internal surface for the roots to feed upon, as the film water upon the outside of these fine soil grains is their feeding ground. The absolute weight of a soil depends upon its absolute specific gravity and the volume of pore spaces in the mass. The average specific gravity of soil material is 2.65. The following table shows the comparative *absolute weights* of some soils:

	Specific Gravit.	Weight per cubic foot Kilos.	Pounds	Weight per acre foot
Coarse sand	1.60	45.5	100.0	4,356,000
Medium sand	1.54	43.5	96.0	4,200,000
Fine sand	1.48	42.0	93.0	4,080,000
Sandy loam	1.30	36.8	81.0	3,550,000
Fine sandy loam	1.32	37.4	82.5	3,590,000
Silt loam	1.24	35.2	77.5	3,400,000
Clay	1.17	33.1	72.6	3,180,000

It is seen that the finer the soil the lighter its absolute weight. Clay soils may range from 60 to 90 pounds in absolute weight, according to their fineness and state of granuation, while sand soils may weigh from 90 to 110 pounds per cubic foot. The terms *light soil* and *heavy soil* as used in agriculture have absolutely no reference at all to the actual or absolute weight of the soil, but solely to the amount of force required in tilling the land. Thus a sandy soil is light because it is easy to cultivate, as the particles move easily. Clays are heavy because the particles stick together, and the plow and other tools drag heavily.

The most obvious physical properties of a soil are its *texture* and color, both of which indicate important differences that influence crops. The texture is determined by the proportion of the different sized mineral particles it contains. This proportion is ascertained by actual physical analysis and is the basis of soil classification. The soil is washed in water in appropriate machinery and the fine and coarser materials separated by centrifugal machines. Some of the coarser particles may be separated by sieves. In this way the soil is separated into fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt, and clay, and the percentages of each present in the soil determine its texture. A high per cent of gravel and coarse sand give a coarse texture, as a high per cent of very fine sand, silt or clay will give a fine texture.

COLOR. There is no longer any doubt but that the color of a soil is important. It indicates some associated properties, causing the color, which influences the yield and quality of the crop. What the colors of the California soils indicate is brought out in the individual descriptions of the soils in Part 4. Just why the color should indicate certain qualities is not always apparent. The color of a soil is not, as a rule, the color of the individual particles, but of material which adheres to the particles. Iron compounds give rise to red, yellow, blue and gray colors; organic matter to blacks and browns, and their combination with iron salts give various intermediate tints and shades.

In the boulder clays of glacial regions, a bluish color is common, due to the presence of protoxide of iron (FeO) resulting from a deficiency of oxygen. Where this comes in contact with carbonated waters, carbonate of iron is formed and the soil is gray; where there is an abundance of oxygen the iron becomes

the sesquioxide (Fe_2O_3) or "iron rust," which has a deep red color. Iron quartz sands and residual shale soils have colors due to the color of the mass of the particles themselves.

A dark colored soil absorbs heat much more rapidly than does a light colored one, and therefore warms up faster. A dark colored soil is generally regarded as a fertile soil. Where this is due to the presence of organic matter this is true, but it is not always a reliable guide, as other properties of the soil must be taken into consideration, such as the climate, altitude, composition, etc. The color of a soil is a valuable guide to the person experienced in the climatic conditions of the given region, as it points out the condition and productiveness of the soil; but one versed in productiveness as related to color in the humid regions of the east is all at sea when he first looks at the soils of the arid and semi-arid regions of the west. A mottled and uneven color may indicate poor aeration which is due to poor drainage. "Rich black soils" have been favorites in the humid regions from the dawn of history, while brownish soils on low ground were believed to indicate acid humus or sour lands; but in the forest such colors would indicate decayed wood. Black soils on the upland prairies of the east often indicate a full supply of lime carbonate and a highly productive soil. Some red soils of the southwest are called "mahogany soils" and are considered prizes, but red soils produced from iron bearing sandstones are often very poor soils whether found in the foothills of the Sierras or in the cotton states of the south.

A red soil is apt to be well drained, for the iron rust, or ferric hydrate, cannot exist in badly drained soils. White soils within the tracts of red lands may show a watery maceration that is injurious. Ferric hydrate has a high power of absorbing gases from the atmosphere, standing next to humus in this respect, while like humus it renders heavy clay soils more readily tilled. The red tint absorbs heat readily, giving a warmer soil, appreciated by orchards and vineyards. Yellow soils owe their tint to the smaller amount of ferric hydrate and share to less degree in its advantages. White soils and light gray soils are regarded with disfavor in the humid regions as meaning a scarcity of both humus and ferric hydrate through the action of stagnant water, and in some localities they are known as "crawfish soils," as they are often inhabited by crawfish, whose holes reach water in a short distance.

In the west and in arid regions generally, white and light gray tints are very common characteristics of the very best soils. They are rich in plant foods ready for use and not affected yet by water. This does not refer to the white alkali spots which are described under the head of alkali elsewhere.

SOIL ODORS. When soil has been recently wet it emits a peculiar odor which is not disagreeable. This odor comes from a neutral organic compound of what the chemist calls the aromatic family. The odor is generally penetrating, almost piquant, and analagous to the camphorated bodies. It amounts only to a few millionths of a per cent and is of little value in most cases in determining the crop value of a soil.

FERTILITY. The fertility of the soil was for many decades believed to be dependent *mainly* upon its chemical composition as tabulated in the old form of chemical analysis, and older works are filled with tables of chemical analysis that are now known to be worthless.

In spite of the tonnage of books on the subject of fertilizers, and fertility, the actual knowledge of fertilizers is still very meager and almost entirely empirical. The *chemical* analysis of a soil still fails to explain its relative productivity. *Chemical* analysis still fails to determine the *amount* of fertilizers needed by lands.

Mineral fertilizers have however a decided influence upon the physical character of the soil, which is really of greater importance than its character as given by chemical analysis. Fertilizers readily affect the granulation of the soils, and all the properties dependent upon that, often correct acidity, increase the permeability of the soil and stimulate diffusion. They furnish heat that may stimulate the dormant spores of some bacteria into life and activity. Fertilizers must be finely divided and used on well aerated soil. The phosphates that are insoluble in water are slowly dissolved by the acid sap of the root hairs, but largely remain inert. Bones decompose in clay soil so slowly as to be of little value. Organic fertilizers such as oil cake, bones, and farmyard, yield only a small portion of their nitrogen during the first year.

The old soil analysis made by extracting the soluble portions with acid and giving the results as soluble and insoluble are now known to be worthless and to mean nothing. A soil

which is utterly barren under certain conditions of climate or moisture may under changed *conditions—not* changed *composition* —become fruitful in the extreme. All of the citrus regions of California are an illustration of this fact. It has been repeatedly demonstrated in this state, where dreary stretches of aridity given over to sand, sage brush and clay, have been converted into the richest of orange groves and vineyards.

If the arrangement of the soil particles is favorable to root action and conservation of moisture, the soil may be made fertile by proper water, and by proper treatment, and is therefore *adapted to* certain crops. A soil containing too large a proportion of fine clay may have too large a proportion of moisture so as to be unsuited to cultivation when saturated and become equally unfit by induration when dry, calling for the admixture of sands to give it a loamy character. A light, porous soil may be fertile when watered, but parts with its moisture so readily as to be barren if subjected to drought, and is benefited by the admixture of some heavier soil. The capacity of a soil to care for the water it receives is the most important of its properties. The fertility of the soil is largely influenced by the cultivation it has received, and by the toxins left by the previous cropping, as all crops leave the soil in a more or less unsanitary condition. "Snow is the poor man's fertilizer," because it heaves, breaks up, loosens, and otherwise changes the physical condition of the soil.

CHAPTER XI

ORGANIC MATTER IN SOIL

Almost every soil contains plant remains. Forest soil contains decayed leaves and stems, sod land is filled with fine roots, and low swampy areas are full of dark organic material. The organic material of soil consists in general of the tissue remains of plants and to a less extent of animals, numerous products of bacterial origin, secretions of algae, fungi, etc., etc. Plants are the chief source of the organic matter, the material going to decay through the action of bacteria and fungi in addition to the purely chemical changes. The chemical composition of the organic matter is as variable as the materials from wihch it is derived and the conditions under which it is formed. Many of these are acid, some act as bases (as ammonia and marsh gas). They react with each other in many ways, but more especially they react with the mineral elements of the soil, forming plant foods, and releasing food elements from the mineral combinations. Nitrogen, which is not a constituent of the rocks, is made available through this organic decay. The percentage of nitrogen varies greatly, some humid soils containing less than two per cent, while some soils of the arid regions contain over twenty-two per cent. Under cultivation the nitrogen in the organic matter is changed to forms available to plants. The organic substances are greater in the soil than in the subsoil, decreasing with depth. Arid soils generally contain less organic matter than the soils of humid regions, and the soils of cold climates contain more than those of the warm climates. Wet soil contains more than dry ones, and clay soils more than sandy ones. Vegetable matter after life is extinguished undergoes complete decay which returns all its matter to dust or gas. This is largely done by bacteria which return the material to a soluble state and is dissolved by the soil solution and becomes food for plants.

Owing to its weak plasticity and great contraction when dried, organic matter hastens the granulation process in clay soils. It binds together and imparts a loamy character to light sandy soils, preventing drifting by the wind and erosion by the rain. It in-

creases the moisture-holding capacity of a soil and improves its power to resist drought. It makes soils warmer by darkening the color and thus increasing their absorption of the heat of the sun. It provides plant food direct, and releases plant food in the soil minerals. Plant roots not only contribute organic matter to the soil but on decay leave openings which aid drainage and aeration. The color of the soil is not, as often supposed, a safe guide to the percentage of organic matter present. Some red, yellow, and brown soils have more organic matter than some black soils and are more fertile. This is notably true on the Pacific Coast, more so than in the east.

TOXIC BODIES. Plants produce waste bodies which may become harmful or toxic to themselves and to other plants of allied species, unless removed or changed in character in the soil. The incompatibility of weeds and crops, of grass and trees, is due to the excretion of one plant inhibiting the growth of the other. The fact that some varieties of plants are not affected by or even destroy the excreta of other plants is the explanation of the beneficial results obtained by the rotation of crops. A pure crystalline body has been obtained, for example, from a cowpea-sick soil, that was not present in the soil before cropping, which is exceedingly toxic to cowpeas when mixed in otherwise good culture medium, but this same substance is not toxic to wheat. These toxic bodies are fatty, nitrogenous or non-nitrogenous organic bodies, unstable and changing rather easily by oxidation into harmless or even beneficial bodies. Bacteria aid in their oxidation or reduction. They are especially apt to form where the aeration is deficient in the soil, as in an overwet soil, and are benefited by better aeration by means of thorough underdraining. Cultivation, if not so deep as to stir up the subsoil, tends to hasten oxidation and the destruction of these bodies. The necessity for guarding against toxic bodies is shown by such experiences as these. Peat soils have given over 400 bushels of potatoes the first year, but in two or three years the yield has dropped to about 40 bushels per acre, although the fertility as regards barley was not noticeably affected. Flax cannot be maintained for more than two or three years continuously, yet the flax-sick soil is not sensibly injured for producing wheat and other crops.. Such soils are not worn out, but are sick, poisoned by the excreta from the crops. The best way to avoid this poisoning of soils by toxins

is to avoid the continual growing of a crop in the presence of its own excreta, products of decay, etc., or, in other words, by the rotation of crops.

LIFE IN THE SOIL. A fertile soil fairly hums with activity. Myriads of forms of life are at work, changing, breaking down, building up. Some are beneficial, some harmful, and some simply neutral or harmless. A vast number of animal and vegetable organisms live in the soil, giving it a flora and fauna scarcely less complex than that which appears above the surface. Soils in which crops grow have been formed by rock decay and plant growth. The mineral portion comes direct from the rock, the humus and other organic constituents have come from living bodies, most of them of microscopic size. The greatest scavengers of the soil are those bacteria that work over and change remains of plants and animals. Some of these change and purify the soil while the crop is growing and after the crop is harvested. Other forms of bacteria bring about the production of substances very toxic to plants.

Bacteria are intimately associated with many of the normal processes going on in the soil and soil solution. They are the most important of all the microscopic forms of vegetable life, for the growth of the higher food plants is absolutely dependent upon their presence. They have many functions, the most important one being that of making soluble the material used as food by the higher plants. They are transformers, not producers, of the fertility in the soil, for they add no plant food but render available that which is already there. The success of agriculture depends largely upon the regulation of the growth of bacteria, for without them the soil would yield no crop. The relation of the soil to crop production involves the growth of these low forms of vegetable life, and the most successful farmer is the one who consciously or unconsciously secures the best conditions for their growth. These minute plant organisms remove dead animals and plants from the soil by decomposition, fermentation, etc., producing the so-called *self-purification of the soils.* Without them the soil would soon be clogged with the remains of past animals and plants.

KINDS OF BACTERIA. There are a number of excellent works on agricultural bacteriology and it is not necessary to go into details of their structure and classification; but only to note

in a general way their relation to soils and soil building. Bacteria may be divided into two classes, those that are beneficial to food plants and those that are injurious. They are exceedingly minute, some being so small that 25,000 laid side by side would only occupy a line an inch long. A single drop of milk may contain 100,000,000. They multiply with extreme rapidity, a single bacterium if unchecked could increase to 17,000,000 of offspring in twenty-four hours, and in five days of unchecked reproduction of all the descendants, could fill the oceans. This fecundity is however checked by lack of food and by the poisons they secrete killing themselves. The round forms are called *micrococcus,* the cylindrical *bacillus,* the curved *vibrio, spirilli,* etc. They are minute unicellular vegetable organisms multiplying generally by division of the cell, but some also multiply by spores which can endure prolonged drying and extreme cold. Those that flourish only in an abundant supply of oxygen are called *aerobic;* those that require little or no oxygen are called *anaerobic.* The aerobic forms are generally beneficial to agriculture, while the anaerobic are generally injurious. Their names and kinds are already legion in number, and each seems to have its own work to do, and its own chosen field to work in, and to act its part in the intention, purpose and design of the Universe.

The *bacillus mycoides* occurs constantly in surface soils and is present in natural waters and is one of the most active of the ammonia makers. The *beggiatoa* or sewage fungus reduces sulphates with the evolution of hydrogen sulphide and the depositing of free sulphur within their cells. The *saccharomycetes* or yeasts derive nitrogen from organic substances and salts of ammonia and carbon from organic matter. The food of the bacteria consists of organic matter with certain necessary minerals. These minerals are phosphoric acid, potash, and lime. The presence of oxygen is necessary. When it is absent or reduced to a low percentage the nitrification of the soil by bacteria stops. A base with which the nitrous or nitric acid formed may unite is necessary, such as carbonate of lime or a small per cent of alkali. An excess of alkali prevents nitrification of the soil. A few bacteria draw their nourishment direct from the air, forming carbonate of ammonia and carbonic dioxide. The particles of rock decomposed by atmospheric agencies are at once covered by this microscopic vegetation which produces organic acids which help to dissolve the particles of rock and cause them to crumble into dirt.

Some bacterial secretions form organic compounds with minerals as when lime is converted into calcium acetate, calcium formate, malate, butyrate, etc., while othre bacteria in turn break these compounds up into others.

MOISTURE. Bacteria demand moisture. A decrease in moisture decreases their activity. They thrive or languish also according to the concentration of the soil solution. Too high a concentration checks their growth or kills them outright. They thrive best at optimum moisture.

TEMPERATURE. The most favorable temperatures range from 70 to 110 degrees F. Thus their action is largely limited to summer temperatures. Dessication, as in desert regions, retards their activities and thorough air drying of a soil paralyzes the bacteria.

NITROGEN FROM THE AIR. Certain low forms separate nitrogen from the air and from organic substances and combine it with the potash, soda, etc., in the soil, but they cannot do this unless the air penetrates the soil thoroughly. Their action is confined largely therefore to the upper three feet of the soil, and stores of insoluble nitrogenous material rest in the subsoils preserved from oxidation until they are brought to the surface. Nitrification takes place deeper than six feet in many of the porous well-ventilated soils of the arid and semi-arid regions of the west.

FAVORABLE AND UNFAVORABLE CONDITIONS. Bacteria are much more numerous in some soils than in others. The structure, tilth, and drainage of the soil determines largely whether the aerobic or the anaerobic forms are to flourish. Each soil possesses but one organism capable of oxidizing ammonia. Soils from one locality have always the same kind of nitrifying ferment. Soils from distant and different lands contain nitrifying organisms which differ from one another in some respects. The upper layers of the soil are exceedingly rich in bacteria but they diminish rapidly with depth and at four or six feet largely disappear except in the soils of the arid and semi-arid regions. Bacteria grow most freely in arable soil containing considerable humus, or rich in organic matter. In these the number becomes very large—from 1,000,000 to 5,000,000 bacteria per gram of surface soil.

The more vigorous the decomposition changes, the higher the fertility of the soil. Black marsh soil shows the highest rate

of decomposition, clay soils show less, and sandy soils the least rate. If a soil is acid bacterial activity is checked, while the activity of moulds and larger fungi are increased. The physical conditions of the soil must favor decomposition. Hard packed soils are inferior to looser soils in this respect. Where oxygen (air) cannot penetrate the soils they become *sour* or acid, checking bacterial activity. Lime may aid in neutralizing this acidity, but aeration will do more. Sandy soils contain less micro-organisms than the loams and clays. Compact clays and loams exclude air, checking nitrification by bacteria. Water logged soils contain but few bacteria.

HIGHER FUNGI. Molds, mushrooms, fungi of all kinds, are agents in the decomposition of vegetable matter so that it may be incorporated in the soil, and be used again in the economy of nature. Some of these may be beneficial to food plants, but their products or excreta are often detrimental and toxic. The thread-like roots (*mycelium*) are able to push between wood fibres and between minute voids in the mineral particles of the soil. The molds are not so rich in nitrogen as the saccharomycetes, or the bacteria, and cannot assimilate nitrogen from the air. They derive carbon from a great variety of organic substances. They flourish only on the surface of the nourishing material and do better in a slightly acid medium than in one that is slightly alkaline. As already stated, if the soil is acid, bacterial activity is checked. It is evident therefore that the activities of molds and the larger fungi are then increased. They break down woody matter, facilitating the work of decay bacteria. They produce the dark colored matter which gives soils rich in vegetable material their dark color. The necessary mineral materials for their growth are phosphoric acid, potash and lime.

There are humble plants, such as lichens, mosses, ferns, etc., which thrive upon what seems to be bare rock. The lichens have no true roots but spread their thin substance over the rocks and secrete acids which etch and dissolve the mineral matter, and the mosses take up the work where the lichens leave off, while the ferns take advantage of the thin soil left by these predecessors in every tiny crevice and gain a foothold. These humble plants shade the surface of the rocks and retain moisture which aids in the further decomposition of the rock and its conversion into soil.

ENZYMES, or unorganized ferments, play a very important

part in the fermentation of manure and the preparation of it for its best effects on certain soils. This fermentation does not proceed well with too much aeration, hence the need for compacting a very loose soil. The subject of enzymes, however, belongs to the study of agricultural chemistry rather than to soils.

HUMUS. The active principle of vegetable mould is called *humus*, a general term for products of the decomposition of vegetable matter no matter what the special agent may be. It is the chief depository of nitrogen, which is the most costly as well as most necessary of all plant foods. Vegetable matter decomposes under the action of bacteria, molds, and enzymes. The composition of humus has not as yet been definitely determined, as it is a mixture of many substances mostly acid. Sawdust humus contains one to two per cent of nitrogen; oatstraw humus contains from two to four per cent; clover humus from four to eight; and meat scrap humus from eight to nine per cent of nitrogen. The humic acid in black soils is almost exclusively in combination with lime. The decay of humus is most rapid in drained and open soils. Clay promotes the accumulation of humus. Few upland arid soils contain over 0.4 per cent of humus, but this humus is richer in nitrogen than the humus of regions of considerable rainfall. The chief functions of humus are to modify the physical conditions of the soil with reference to texture, moisture, absorption of heat, and to hold in suitable form the nitrogenous principles of vegetable matter; but it is not assimilated directly itself. It makes soils lighter and of better tilth, enables them to absorb more moisture, and makes them warmer.

ANIMAL LIFE IN THE SOIL. *Earthworms* not only obtain nourishment from the organic matter of the soil, but take in the inorganic. They pass the soil through their bodies leaving it in a granulated condition in the "casts" which they deposit. It is estimated that in a favorable soil in a humid climate as much as eleven tons of dry earth per acre passes through their bodies and that 0.18 per cent of their secretions consists of soluble nitrates in the form of ammonia. They modify the soil mechanically by bringing to the surface particles of the subsoil; the holes left by them increase aeration and drainage, and the soil is made more porous and easily pulverized. They affect the soil chemically by acid and alkali reactions as the soil passes through their bodies, leaves and other organic material being converted largely

into humus. Finally the bodies of the worms themselves become fertilizing material and food for the bacteria and plant roots. Worms naturally seek heavy, compact, and moist soils where they are of the most benefit; the sandy soils which do not need them contain few. *Ants* with their busy colonies bring soil from the depths and heap it on the surface, giving drainage, aeration, and mixing the soil with subsoil. *Beetles* and a myriad of other burrowing insects and animals cause movement of the soil particles and aeration and drainage and incorporate a considerable amount of organic matter with the mineral matter present, and at last contribute their own bodies to the sum total.

ACID SOILS. Soils rich in decaying vegetable matter may show a distinct acid reaction. Even very acid soils contain but little acid, or acid salts, soluble in water. The humic and ulmic acids and their salts are chiefly responsible for the harmful acidity of soils. Acidity exerts a marked influence upon the crop-producing power of the soil, as it affects both its physical and chemical condition, (1) through its action upon the microorganisms which in turn modify the physical condition, and (2) by the direct action of the acids upon the tender rootlets. Crops grow best when the soil is neutral, that is, neither acid nor alkaline. Lime and limestone are the best correctives. Soils in the arid regions are more apt to be alkaline than acid.

CHAPTER XII

SUBSOIL. SOIL MOVEMENT. SOIL PERMANENCY

SUBSOIL. This is the part next below the surface soil, and the distinction between soil and subsoil lies almost wholly in the color and texture, the composition being very much the same, as a rule. Generally the subsoil is soil in the process of making, or raw unfinished soil, as the surface soil is often only the weathered or rotted subsoil; and the subsoil in turn is only a phase of the rotted bedrock below. The character of the subsoil affects the water-holding capacity of the soil above. Thus a gravel subsoil, or sand subsoil, gives perfect drainage, while a clay subsoil interferes with drainage. The nature of the subsoil affects the productiveness of the soil. An impervious subsoil, or a very loose sandy one, confines the productive zone to the top soil. An old English ballad says:

"Clay on sand is money in hand;
Sand on clay is money thrown away."

While this may be true in the humid climate of the "right little, tight little island" it is untrue in an arid climate. Climate modifies the relation of the subsoil to the soil. In humid regions of large rainfall and seepage, the subsoil is finer and more compact than the soil from the washing downward of the finer particles. In the arid regions the subsoil is inclined to be coarser than the soil above. In humid regions the subsoil is less productive than in the arid regions owing to the greater amount of leaching. Occasional deep plowing brings some of the subsoil to where it is exposed to the atmospheric weathering, and the action of plant roots, and humus, so that it becomes in time surface soil. Most soils formed under arid conditions are sandy, and there is little or no clay to be washed down into and compact the subsoil, the result being that air and water circulate to greater depths than in the soils of the humid regions. The distinction between soil and subsoil is slight in the arid regions; or the soils are so deep that there is no subsoil within the depths which tillage can be made to reach. There are exceptions to this

rule in the arid regions, as in the case of marsh, swamp, lacustrine soils, or where bedrock comes close to the surface. In the arid regions the farmer may be said to own three or four farms, one above another, as compared with the same acreage east, for he finds hop roots going down as much as fourteen feet without lateral expansion; grape roots going down twenty feet; alfalfa twenty-five to thirty, etc. Another illustration is the fact that the earth from cellars and house foundations is fearlessly put onto gardens on which fruit, flowers, and vegetables grow in the first year. The irrigator also levels slopes, hillsides, and terraces with no idea of discrimination between soil and subsoil, and the results justify his action. Calcareous or limey subsoils enable the farmer to enrich the surface by deep subsoil plowing. In shallow soils the nature of the subsoil should be closely observed.

SOIL MOVEMENT. The predominant factor in the production of a crop is the amount of available mineral plant nutrients in the soil, joined to the physical condition of the soil. For years the idea has prevailed that a given field or soil mass stays in place indefinitely and without changes, except such as are produced by cultural methods. This is not at all the case. It is now known that the soil must be dealt with as a living thing in the sense that it is ever in motion. The root of the plant is always in action, while the plant lives; the soil solution (the blood of the soil body) is always in motion, and if it stops and is stagnant the soil is dead; the soil atmosphere is constantly in motion and changing, for the soil must breathe; the life of bacteria, etc., in the soil affects its sanitary condition or health. Soil is not a dead, inert mass, but in constant action. The particles are in motion from freezing and thawing, and every change in the moisture content is accompanied by motion. The activities of insects, earthworms, burrowing animals like beetles, gophers and moles, are constantly translocating soil material. Ants bring about large transfers from lower to higher levels, and their borings admit air and water to the deeper lying portions, promoting further chemical and physical changes. The angleworm or earthworm is one of the most important of the soil builders, loosening, aerating, fining and draining the soil and subsoil. A soil is not dead, but teems with life and hums with activity. Countless organisms visible only to the microscope are ever at work soil building, soil destroying, and soil changing. Water action in

translocation is restricted only by the fact that water can run down hill only, but the wind is constantly in action and blows uphill as well as down, and sidewise. It is a striking fact that articles left lying on the ground gradually sink below the surface. Even a layer of ashes or lime will sink as a layer and be found a few years later as a distinct stratum below the surface. The slow and unnoticed drift of materials backward and forward by wind and water are ever affecting the soil. The accumulations of dust, so evident to every housewife, are unnoticed in the field by the average farmer, yet they are very important, for they amount to several tons per square mile, or section of land each year.

It is a fact that must be taken into consideration that the soil of a particular field, especially one under cultivation, is not just the soil that was there a few years ago, or just the soil that will be there a few years from now; and that this movement at *normal* is beneficial and an important factor in maintaining fertility, but when *abnormal,* as under wind erosion, etc., it is baneful. The control of the wind action is met by windbreaks, cover-crops, etc., and that by water erosion by forestration, rotation schemes, cultural and other methods. The persistence of a soil is the persistence of the soil layer rather than of the individual particles, just as the maintenance of our own bodies consists in maintaining its *health and form* while the individual particles of which it is composed are forever changing. Soils are always in the process of change, and soil conditions are not static, therefore, but dynamic.

SOIL DETERIORATION. Soils vary greatly in their power of endurance. Most soils deteriorate through neglect and insufficient and injudicious cultivation. They deteriorate even with fairly good treatment under the one-crop system, whether it be wheat, corn, cotton or tobacco. They frequently deteriorate through erosion where the top soil is removed, leaving the unweathered subsoil as the medium of growth. A complete drying out of the soil for a prolonged period usually brings beneficial changes. Infertility is often due to the presence of toxin bodies, and other causes already mentioned.

SOIL PERMANENCE. Many gloomy predictions have been made regarding the probable failure of the soil to support the increasing population of the earth. Such predictions seem

absurd to soil students. Proper drainage, cultivation, aeration, rotation and fertilization maintain the sanitary conditions in the soil, and renew the productive capacity of so-called *dead* and *wornout* soils. If the practice of agriculture has ruined land, the science and art of agriculture must restore it. If the youth of the civilized nations were required to take a three years' course in agriculture instead of their militia training, the talk about wornout soils would die out with the talk of the necessity of colonization for the excess population. The work of the U. S. Bureau of Soils alone in several states shows that there is no actual exhaustion of the mineral plant foods in the soils that were called exhausted, wornout, and impoverished, because agriculture had declined there. Soils are not impoverished of their mineral plant food contents within the finite range and experience of human knowledge. The Bureau has proven that a mere change in cultural methods has worked wonders, and in five years many of the so-called exhausted soils yielded better than formerly.

The older agricultural soils of Europe and Asia contain the same common rock-forming minerals of the newer soils of the United States, and there is no essential difference in their chemical composition. The lands of Europe have been occupied for a thousand years without a noticeable reduction of the plant food element as compared with the newer soil of this country.

Many sections of China have undoubtedly supported an agricultural population for centuries longer than the soil of Europe, but there is no sign of deterioration of these soils. The soils of Europe are not only not wearing out but are improving in their yield. This increase is due to better methods of cultivation, care in the selection of seed, increase of livestock, use of scientific fertilizers, proper drainage, aeration, systematic rotation of crops, etc. It is aided by the fact that one family and its descendants occupy the same farms one generation after another, and become intimately acquainted with each soil and its peculiarities. The fertility of the soil can be temporarily impaired, but soils do not wear out in the sense that this term has been used in the past, and there is no permanent wide-spread exhaustion or deterioration of the soil. The soil will not be exhausted of any one or all its mineral food contents, but is safe as a national asset as a means of feeding and clothing mankind for the ages yet to come.

CHAPTER XIII.

CLASSIFICATION OF THE SOILS

In any one of the provinces of California will be found soils derived from the same materials formed through the same agencies, and having certain chemical and physical characters in common, but differing in texture, and exhibiting all gradations from clay to gravel. The soil minerals found in the soil provinces do not differ materially in character, but the soil peculiarities of each province are the result of different agencies, such as climate, topography, etc. It makes a difference whether the soil is in a humid, arid, or semi-arid province. The differences in the properties of the several grades of materials, or size of the mineral particles, gives rise to various soil types, classes, or groups.

SOIL SERIES. A common name taken from some typical locality is given to each soil series, such as the Sacramento series, Imperial series, or San Joaquin series, showing types *formed in the same general way.*

SOIL CLASSES. All those soils having *the same general texture,* no matter how derived, constitute a *soil class,* as the sandy loams, sands, loams, and clays. Every farmer knows that there is a great difference between sand and clay, that they must be handled different, and are suited to different crops; but he does not know always that the cause is due to the different size of the soil units.

SOIL PARTICLES. The grade of material entering into a soil is determined by the size of the *particles,* the measurements being in millimeters. A millimeter is the thousandth part of a meter or .001 m, and is equivalent to the 0.03937 part of an inch. It is denoted by writing mm. after the figures as 1 mm. is a millimeter. The standards are as follows:

Gravel	2.	to	1.	mm.
Coarse sand	1.	to	0.5	mm.
Medium sand	0.5	to	0.25	mm.
Fine sand	0.25	to	0.1	mm.
Very fine sand	0.1	to	0.05	mm.
Silt	0.05	to	0.005	mm.
Clay	0.005	to	0.0000	mm.

Material larger than 2 mm, or 0.08 of an inch, is classified

as pebbles, cobbles, boulders, etc., and is not included in the soil analysis, but described in connection with the land.

The combination of *different percentages of the particles* or units, or the combination of these units in different proportions, form the soils known as sand soil, fine sand soil, sandy loam soil, fine sandy loam, loam, silt loam, clay loam, and clay soils. There are also phases of these soils, as gravelly sands, loamy sands, stony loams, or stony clays, which may in certain provinces be included in a group, and in other provinces be set aside as subordinate soils of little agricultural value.

SOIL NAMES. All those soils having *the same general texture,* no matter what their derivation, have the same class name, as sandy loam, silt, fine sandy loam, etc. They are named according to the relative proportions of the different particles or units entering into their composition. The rules for naming are as follows:

Soils containing:

(1) *Less than* 20 *per cent of silt and clay* together, are called:

COARSE SAND, if they contain more than 25 per cent of fine gravel, and less than 50 per cent of any other grade.

SAND, if they contain more than 25 per cent of fine gravel and medium sand, and less than 50 per cent of fine sand.

FINE SAND, if they contain more than 50 per cent of fine sand, or less than 25 per cent of fine gravel, coarse and medium sand.

VERY FINE SAND, if they contain over 50 per cent of very fine sand.

(2) *From* 20 *to* 50 *per cent of silt and clay,* are called:

SANDY LOAM, if they contain over 25 per cent of fine gravel, coarse and medium sand.

FINE SANDY LOAM, if they contain over 50 per cent of fine sand, or less than 25 per cent of fine gravel, coarse and medium sand.

SANDY CLAY, if they contain less than 20 per cent silt.

(3) *Over* 50 *per cent of silt and clay* are called:

LOAM, if they contain less than 20 per cent clay and less than 50 per cent silt.

SILT LOAM, if they contain less than 20 per cent clay, or over 50 per cent silt.

CLAY LOAM, if they contain 20 to 30 per cent clay, or less than 50 per cent silt.

SILTY CLAY LOAM, if they contain 20 to 30 per cent clay, and over 50 per cent silt.

CLAY, if they contain over 30 per cent of clay, etc.

HEAVY AND LIGHT SOILS. The sands, sandy loams and fine sandy loams are generally referred to as *light soils*. The loams, silt loams, clay loams, and silty clay loams are referred to as *heavy soils*. This refers not to the weight per cubic foot of the soil, but to the draft required in plowing, cultivating, etc. Fine material of this kind is held in a plastic or coherent condition and requires more power to plow and cultivate than it does on loose or only slightly coherent soils of the sandy groups. The yields are also generally larger and more bulky on the loam and clay groups than on the sandy groups and this requires heavier teams for harvesting the crops as well as to prepare them.

DEPTH CONSIDERED. In naming a soil the texture of the surface soil and of the subsoil to a depth of three feet in the humid states and six feet in the arid states is taken into consideration. There are soils that have a sandy surface soil and a clay subsoil, and occasionally there is a clay soil that has a sandy subsoil, affecting the adaptability to crops. When a soil is referred to by name as the Imperial sandy loam, the term *soil* in this sense includes both the top and the subsoil. In sampling soils, the top soil and the subsoil are kept separate, and if the subsoil shows two layers of different texture these are separated also.

SOIL SERIES. Where soils have a common origin, and differ only in texture and are alike in color and physical properties other than those affected by texture, they are arranged in what is called a *series,* having the soil generic name with qualifying textural terms. We have for example the Placentia soil series, named for the type locality around Placentia, in Orange County, California. This series is divided into classes known as the Placentia sandy adobe, Placentia sandy loam, Placentia fine sandy loam, Placentia loam, Placentia loam adobe, Placentia clay loam, and Placentia clay loam adobe. The same type of soil receives the same name, and members of the Placentia series are found around Riverside, Redlands, Perris, and other localities remote from the type locality. Members of the Hanford series are found also around Los Angeles and San Bernardino.

Other things being equal, the water holding capacity of the soil will vary as the texture varies; the light sandy types holding on an average not over four per cent of water, while the clay members may hold as high as twenty per cent of moisture. This difference in moisture creates a corresponding difference in the soil atmosphere and oxidation is usually more rapid in the sandy than in the clay members of a series. The effect of these differences of soil texture upon the adaptation of soils to crops and upon crop production is well known, and is stated under the descriptions of the soils. The *moisture* of a soil is defined as follows: *wet,* when water drips from a piece held in the hand without pressing; *moist,* when water drips from a piece pressed in the hand; *fresh,* when no water drips from a piece pressed in the hand, although it is evidently present; *dry,* when there is little or no trace of water present; and *very dry,* when the soil is parched. The depth of soil is indicated in terms which have their equivalent in inches, thus, *very shallow* means less than six inches; *shallow* means six to twelve inches; *moderate* means twelve to twenty-four inches; *deep* means from twenty-four to thirty-six inches; and *very deep* anything over thirty-six inches. In doing the field work of classifying soils, all features are taken into consideration which in any way appear to influence the relation of the soil to crops. The classification is based mainly but not wholly upon the physical properties and conditions of the soil. Any chemical features such as deposits of marl, of highly calcareous soils, or of highly colored soils is considered. The character of the native vegetation, or its absence, and the condition of crops growing is noted as a prominent factor. The topography of the country is often a safe guide in outlining the boundaries of soil conditions.

Local variations in the character of the soil less than a quarter of a mile in extent are generally ignored, unless this variation constitutes a very prominent feature, such as a strip of meadow land along a stream, or unless there are a number of small areas by which character is given to the district, such as rocky areas, small each, but extending in the aggregate over large areas. For example, Meadow Land is not only a distinctive feature, but it is a very fine sediment of silt and very fine sand, which is easily recognized as distinct from the other soils of the valley. Loam is a grade coarser than the meadows, and the character of the vegetation and the relation of crops in the field is very marked. In some places the classification of the

soils has to be made mainly from the distribution of the native vegetation, where the different classes of soils vary but little in their physical and chemical properties, but show a very great difference in their native vegetation and in their adaptation to crops. The survey of alkali lands involves special determinations and observations in the field. There should be a soil map, the alkali map, the underground water map, and where black alkali, or sodium carbonate exists in appreciable quantities, a separate map showing the distribution and percentage of this pernicious substance. As a rule, the clay soils on the flats and draws contain the greater amount of alkali, the loam soils next, then the sandy loams, and finally the sandy soils. This is due partially to texture and its influence on the drainage, and partially to the physiography of the country as to drainage.

ADAPTATION OF SOIL TO CROPS. The influence of abrupt topographical changes, as our mountain ranges and elevated plateaus, tend not so much to modify the character of the soil, as they do the character of the crops that may be raised to advantage. The slope and the elevation has the effect of adapting the land to special crops, and call for different methods of soil management. The climates of each province are widely different and affect the class of crops that may be raised, as the desert sand may be well adapted to date culture, while sands in a colder climate would not be. There is remarkably little true clay in California such as is found in the east, but sands, loams and silts predominate. Some soils have adobe properties which are unusual in the east. The soils of the west are generally freer from toxic organic bodies than eastern soils, and are capable of producing maximum crops under irrigation and intensive culture. Plants develop a much deeper root system than on the soils of the east. The fact that there is little difference in texture between the soil and subsoil, that rains are infrequent, the atmosphere dry, and the surface evaporation rapid, enables the farmer to maintain a more efficient surface dry mulch, making it possible to produce good yields of crops with remarkably light rainfall, and frequently without any rainfall at all, during the growth of the crop. The climate limits broadly the zone or area in which certain field crops may be grown, and affect the yield and quality of the crop. In California, the arable lands vary from below sea level to elevations 6,000 feet above. The greatest precipitation comes in the winter season. There is a

wide difference in the provinces in the relative humidity and sunshine, as there are differences in the range of temperatures daily and seasonal; and there are differences in the length of the growing season. There are also differences due to exposure, slope, etc. All of these points have to be taken into consideration in determining the special fitness of a soil for any particular grade, quality or kind of product.

PART V

CHAPTER XIV.

KEY TO CALIFORNIA SOILS

The following artificial key to the soils of the state gives a method for identifying or classifying a soil tentatively from its origin, appearance, or position, and finding out what series it belongs to or most closely resembles. While it covers the principal series it is impossible to include all the purely local soils and their variations. These may be identified locally by comparing them with other members of the same class.

Thus if a soil is recognized as a silty clay loam, a comparison of the soils described under that head will show wherein it resembles or differs from those already identified and classified, and whether it belongs to an established series or not.

The broad natural divisions are based on the origin of the soils, viz:

A—RESIDUAL SOILS.
B—COLLUVIAL SOILS.
C—ALLUVIAL SOILS.

RESIDUAL SOILS. The residual soils may be subdivided as follows:

Derived from granitic rocks: Black color, Portersville series. Brown, Daulton. Chocolates, Arnold, red, Media.
Derived from granites, slates and volcanic rocks: red, Sierra.
Derived from granitic and metamorphic rocks: Pleasanton.
Derived from granite and shale: brown, Encinal.
Derived from sandstone: Contra Costa.
Derived from sandstone and shale: Altamont, Santa Cruz.
Derived from shales and conglomerate: Watsonville.
Derived from limestone: Diablo.
Derived from lava: Tuscan.
Derived from metamorphic rocks: Vallecitos.
Derived from the Red Bluff formation: Tehama.

COLLUVIAL SOILS. The colluvial soils may be divided as follows:

Derived from granitic or volcanic material: Dark colored, Maricopa. Reddish brown with clay or sand subsoil: Placentia.

Derived from granodiorite or gabbrodiorite: Black from hornblende or mica, Sheridan.

Derived from andesitic rocks, tuffs and breccias: Sutter.

Derived from shale: Salsipuedes, Danville.

Derived from sandstones, shales and shaly sandstone: Oxnard.

Derived from sandstones, shales, conglomerate, and volcanic rocks: Sites.

Derived from recent marine deposits: Indio.

COLLUVIAL, modified by mixture of alluvial, valley soils: Dublin, Livermore, Sunol, Ulmar.

ALLUVIAL SOILS—WELL DRAINED:

River and stream deposits:

Along the Colorado River bottom: Gila.

On the Colorado delta: Imperial.

From shales and sandstones: Yellow brown, Esparto. Black, Pajaro.

On bottom lands: Orland.

On lower benches and plains: Yolo.

At base of foothills: Oakdale.

On minor creek bottoms: Elder, Mocho.

On Upper Valley Plains:

Gravelly bottoms of intermittent creeks: Anderson.

Upper valley floors: Arbuckle, Maywood.

On broad deltas, cones, sloping plains: Fresno.

River and delta plains: Hanford.

On upland mesas: Santiago.

On plains: Gridley.

From Red Bluff formation: Corning, Kirkwood, Redding.

ALLUVIAL SOILS—POORLY DRAINED.

Lacustrine origin, temporary lakes: Capay.

Coastal, drab, rushes, tules, Alviso clay. Black: sloughs and marine salts: Galveston clay.

Recent stream deposits, overflowed: Sacramento, Alamo, Feather.

Swamps: Santa Rita.

Wash from more elevated soils: Lime hardpan, Stockton. Many local soils.

Valley plains: Red, hardpan: Madera, San Joaquin.

(A) RESIDUAL SOILS. These are derived from the direct weathering of rock in place. They are gravels, sands, or clays, or other soils that are the actual residues or products of rock decay, *occupying the sites* of the rock masses from which they are derived. There may be as many kinds of residual soil as there are kinds of rock. They are sometimes called *sedentary soils in place.* They may be shallow and marked by abundant outcrops of rock, boulders and rough rock areas, or they may accumulate to great depth and the underlying rocks not exposed except where the erosion has been excessive. They generally contain sharp fragments of the undecomposed bedrock which increase in size and number downward in the soil. They are highly colored as a rule, usually red or yellow from the accumulation and alteration of iron salts. Thus a gray limestone may produce a red clay soil. They are seldom uniform in texture and the clays are usually gritty. They are commonly found or *occur* on rock plateaus, on plains where bedrock is near the surface, and in granitic, volcanic and basaltic areas. They occur also along the bases of mountains, foothills and covering low hills and rolling ridges. The texture of these soils and the surface slope is such that there is usually good drainage.

PORTERSVILLE SERIES. The type locality is in the Frazier Valley, near Portersville, where these soils occur along the lower slopes of the foothills. They are derived from the underlying granite, but are more or less modified by alluvial agencies and wash. The color is generally black from organic matter, but may vary from dark red to brown locally.

DAULTON SERIES. The type soil is found in the Madera district. They are formed by the decomposition of the granite and quartz rocks of the foothills. The color is brown to red brown. Not extensive, and generally used only for dry farming to grain.

The *Arnold soils* of the Modesto-Turlock area occupy the foothills of the Sierras. These hills are of sedimentary origin and were once part of a gently sloping smooth ocean or lake bed that occupied the Great Valley. When this portion was

raised above water it was carved by erosion into its present form. The predominating outcropping beds of the southern hills of this area were very largely granitic in origin, weathering into the chocolate-colored soils which have no true hardpan and are underlain at various depths by the sedimentary formations from which they were derived. They have been greatly modified by rain, wind, plant life, and other agencies since first formed.

MEDIA SERIES. The types soils are found in the Madera area on the high rolling foothills of the Sierra Nevada. They have a typical red color.

SIERRA SERIES. The type soils of this series cover large areas of valuable fruit and grazing lands along the western slope and base of the Sierra Nevada mountains. They comprise soils derived from the weathering of granitic rocks, diabase, altered rocks, (such as amphibolites, slates, serpentine, and volcanic materials) with a slight admixture of colluvial and alluvial material from the same sources. They are generally of light red to deep red color, and of somewhat compact structure. They occupy rolling and frequently mountainous districts and foothills, and usually support a more or less heavy growth of brush and forest trees.

PLEASANTON SERIES. The Contra Costa Hills on the west and the Mt. Diablo Range on the north and east, in the Livermore area, are composed of Tertiary and Cretaceous sandstones, limestones, conglomerates, and argillaceous shales, with granitic and metamorphic rocks. The Pleasanton series are the residues of granitic and metamorphic rocks and occur on the uplands.

ENCINAL SERIES. The Encinal sandy loam occurs in the region of Elkhorn Slough on the southern slope of the Monterey Hills. It is dark brown to drab gray in color, with a whitish subsoil. The soil contains sharp fragments of granitic gravel and shale.

CONTRA COSTA SERIES. The type soils are found in the Livermore area and are derived from the weathering of the Tertiary and Cretaceous sandstones of the Contra Costa and Mt. Diablo Ranges. See Pleasanton.

ALTAMONT SERIES. The type soils are found in the Livermore area, and are formed by the decomposition in place

of the shales and conglomerates of the Contra Costa Hills and the Mt. Diablo Range. See Pleasanton.

SANTA CRUZ SERIES. The type soils of this series are found in the Santa Cruz mountains and are derived from the weathering of shales and sandstones in place. They are red to dark brown in color.

WATSONVILLE SERIES. This series is derived from shale, or from shale and conglomerate. They occupy low rolling ridges and hills that form the plain north of the Pajaro River. They are dark brown to red in color.

DIABLO SERIES. The type is found in the Livermore area on the uplands, and are formed by the weathering of Cretaceous limestones of the Mt. Diablo range. They are brown in color. Fossil oysters are common in the soil in the type locality.

TUSCAN SERIES. The type soils are found in the Red Bluff area, on the east side of the Sacramento Valley. They are shallow soils, reddish brown in color, and are formed by the weathering of the lava flows from Lassen Peak region.

VALLECITOS SERIES. The type soils are found in the Livermore area on the uplands, and are the result of the weathering of the metamorphic rocks of the Mt. Diablo Range. See Pleasanton.

TEHAMA SERIES. The type soils are found in the Red Bluff region lying above the alluvial plains along small streams, on the west side of the Sacramento Valley. They are derived from the weathering of the Red Bluff formation.

(B) COLLUVIAL SOILS. These take their name from *collis* (a hill), as they are soils that move or creep slowly down moderate slopes through the action of expansion and contraction from heat and cold, and through the action of gravity, frost, and rain wash. They consist of alluvium in part from wind sweep and water wash, and also contain angular fragments of the original rocks. They consist of unassorted colluvial, or only partially sorted alluvial material formed by the soil creep, by direct wash from the mountain side, and by the deposit of intermittent, shifting, torrential streams. They occur as talus and cliff debris, and as avalanche and slide material. They are found on hillsides, rolling and hilly uplands, on mountain slopes, on delta cones or fans, debris aprons, and the sloping plains of filled val-

leys. They also occur in stream valleys as the product of a series of secondary fans or cones emerging from adjacent more elevated slopes or mesa lands.

MARICOPA SERIES. These soils are found in many localities and are derived from a variety of rocks, but generally from those of granitic and volcanic character. They are generally of dark color and loose porous structure, well drained and free from alkali.

PLACENTIA SERIES. The type locality is around the town of Placentia in Orange county. They are distinguished from the Maricopa by the prevailing reddish brown to reddish gray color, and in being underlain by indurated sands, shaley sandstones, distintegrated granite, or by heavy compact red loams or clays of tough impervious adobe structure. Generally well drained and free from alkali, but somewhat refractory to cultivation. They are widely distributed, especially in the southern part of the state.

SHERIDAN SERIES. The Sheridan sandy loam is a black friable soil found in the Sacramento area. The characteristic black color is due to the large proportion of black hornblende and biotite mica crystals which it contains.

SUTTER SERIES. The type locality of this series is in the vicinity of the Marysville Buttes. They are dark brown to black in color and underlain by brown or yellow loams. They are made up of material from the Marysville Buttes, which are composed of andesitic rocks, tuffs and breccias.

SALSIPUEDES SERIES. The Salsipuedes loam of the Pajaro Valley has been washed down from the shale mountains and adjacent hills. It is brown in color and is underlain by loam or sandy loam.

DANVILLE SERIES. The type is found in the Livermore area on the valley floor and is formed from the shales of the Contra Costa Hills and Mt. Diablo Range, as shown by the sharp shale fragments in the soil. It is somewhat modified locally by alluvial wash.

OXNARD SERIES. This series consists of delta plains deposits, colluvial and alluvial wash from the foothills. They are derived mainly from sandstones and shales and occur on rolling hills; elevated and dissected mesa lands and plains, and delta

plains. They are less elevated than the Maricopa, and are lacking in the granitic material of that series. They are generally dark colored, and underlain by heavier subsoils which do not have the red color and adobe structure of the Placentia series, which occupy similar topographic positions.

SITE SERIES. These are found on the slopes and across the narrow valleys of the outer range of hills forming the western edge of the Sacramento Valley in the Woodland area. They are generally brown in color, with variable subsoils and are derived from the sandstones, conglomerates, shales, and volcanic rocks of the Coast Range.

INDIO SERIES. These soils are wholly wash from the surrounding mountains of the Riverside and San Jacinto ranges. They range from sea level to about 250 feet below sea level. The surface of the Coahuilla Valley is covered with small shells, showing that the soils were deposited under water and are the weathering of recent marine deposits. They are all very sandy, loose, friable, light colored, and show particles of quartz, mica, granite, and volcanic ash, and are more or less wind blown.

COLLUVIAL, MODIFIED BY MIXTURE OF ALLUVIAL. Some soils are distinctly colluvial in origin and yet are modified by considerable quantities of alluvial material washed into them. The DUBLIN, LIVERMORE and SUNOL soils of the Livermore area are valley soils, having largely a common origin and position but differing in character and crop value. The Dublin is black in color, and derived from shale; the Livermore is brown in color and poorly drained; the Ulmar is brown in color and marked by hogwallows. Other characteristics are given in the local description. The Sunol is a brown loam carrying slate fragments, and has a clay loam subsoil.

(C) ALLUVIAL SOILS. These are recent deposits in valleys, on flood plains, bottom lands, and deltas of the detritus, brought down chiefly by water. This includes recent alluvium, marsh and swamp deposits, clays, and loess and adobe in part. Such deposits are more or less distinctly stratified or bedded. Their productiveness is due to their fine texture, their frequent renewals by deposits from flood waters, and the variety of elements of which they are composed. They are the soils of the valleys, flood plains and lake borders, past and present. They occur all along the main stream courses, especially in the lower

lands, where during flood season the water usually leaves the banks and spreads over the flat lands adjoining. The sediments carried down from the mountains and higher ground are spread out over the bottoms in thin layers during flood time. Nearest the stream, or wherever the current is swiftest, the coarser grades of sand and gravel are deposited and build up the coarser textured soils. Further away from the stream, or wherever the current is sluggish, the finer sediments like fine sand, silt and clay are deposited, building up the finer textured soils. Along the larger rivers the material may show distinctly that it comes from the mountains of the interior. Along the smaller streams the soil consists of the wash from the adjacent foothills and plains soils. They often occur in long continuous bodies, paralleling the courses of present or former streams, along the smaller intermittent foothill and plains water courses, and as distinct alluvial fans where the smaller streams flow into basins. Some are deposited in intermittent lakes, some in the swamps at the margins of lakes and some in the swamps and bayous covered by ocean tides. Many of the low-lying members are subject to overflow, or the drainage may be deficient owing to the flatness of the surface, character of the subsoil, or to other local causes. Being of mixed origin, their general character may vary from one extreme to the other, both as regards physical and chemical composition. In the upper portions of the valleys, where the slope is steep and the velocity of the waters is high, cobbles and gravels are dominant. As the slope decreases, first coarse and then fine sand will be prominent, while still lower down the finest sand, then silt, and finally clay will dominate. As streams in flood vary in velocity from time to time, deposits of different texture will often alternate with one another on the flood plains. This is a distinguishing mark of alluvial soils and is noticeable on terraces, benches, and mesas, due to the elevation of the land or to the depression of the river channel. On the lower slopes of hills bordering alluvial valleys the colluvial slope soils often alternate with the alluvial deposits. The alluvial soils may be divided in the two natural divisions of well drained and poorly drained, and these in turn subdivided according to their principal characteristics.

GILA SERIES. These soils are formed from the deposits of the Colorado River in its annual overflow. They are red brown in color, loose and incoherent.

IMPERIAL SERIES. They occur in the Imperial Valley, which is a portion of the Colorado River delta. This region was once occupied by a northern extension of the Gulf of California into which the Colorado River poured its sediment-laden stream, building up an extensive submarine delta. Later the region became a lagoon shut off from the sea. The marine and lagoon phases are marked by extensive beach line deposits. The lagoon phase fluctuated between salt and brackish water stages and was later replaced by an arid basin that at its lowest point was 260 feet *below* sea level. Since that time repeated overflows of the river have carried suspended sediments into the basin, burying the older deposits at various depths. The surface materials from which the soils are derived are not continuous, but form thin irregular lenses of sediment. The chief agent now at work is the wind, which excavates, transports and deposits a large quantity of material annually. The greater proportion of the soils consist of clay and silt, the heavier soils predominating. They differ from the Gila series in being underlain by heavy sediments of close nature.

ESPARTO SERIES. These soils are derived from material transported by the minor streams of the foothills of the Coast Range, and are of recent origin. They originate from shales, sandstones and clays of the lower range of hills, and overlie the older formations of the valley plain. They are generally yellowish brown in color.

PAJARO SERIES. These are derived from shales and sandstones, with an admixture of igneous and crystalline rocks. They extend from the river to the hills of the Pajaro Valley. The color is dark brown to black, due to the high per cent of humus.

ORLAND SERIES. These consist of material from the former and recent deposits of Stony Creek, in the Colusa area, with an admixture of wash from adjacent soils, and occupy the lower benches and plains.

YOLO SERIES. These soils are derived from material transported by Cache and Putah creeks in the Woodland area. They are deep, silty, and sandy, and generally brown in color.

OAKDALE SERIES. These are recent soils of old overflow channels in the Modesto-Turlock area, with wash from adjacent

soils. They are brownish in color, micaceous, and underlain by lighter subsoil. They occupy a lower position than the Arnold along the base of the foothills and on stream bottoms.

ELDER SERIES. The type soils are found in the Red Bluff area, which covers the extreme northern part of the Sacramento Valley and its adjacent elevated plains. The soils are derived in part from the original deposits of the valley and from modern alluvium brought in by the streams that traverse the area. The Elder series are dark in color, deep and friable, and occupy the alluvial bottoms of the major streams coming from the Coast range on the west side of the valley.

MOCHO SERIES. The type soils are found in the Livermore area lying between the Contra Costa Hills and the Mt. Diablo Range. They occupy the bottoms of the valley and are still in the process of formation, being purely alluvial.

ANDERSON SERIES. These consist of reddish, gray, or light red soils, occupying upper valley plains and the bottoms of intermittent streams. They are usually gravelly, and underlain by gravels or compact clay.

ARBUCKLE SERIES. These are derived mainly from coarse conglomerates and slates deposited by streams on upper valley floors, and are of comparatively recent origin. They are generally of gray color and overlie clay formations.

MAYWOOD SERIES. The type soils are found in the Red Bluff area. They occupy the terraces and alluvial fans of the streams on the upper valley floor and are marked by terraces. They occur on the west side of the Sacramento Valley, are grayish in color, and more friable than the Tehama.

FRESNO SERIES. These are characterized by prevailing light gray color, but are sometimes light red to reddish brown. They are generally underlain by subsoils of fine ashy texture, light color, and compact close structure, usually separated from the overlying soil by an alkali carbonate hardpan of white or light gray color. The series is composed of old delta deposits formed by shifting streams and mountain torrents, and occuring as broad, low, alluvial delta cones. They occupy gently sloping plains or slightly rolling valley slopes. The origin is mainly granitic, but from volcanic and sedimentary rocks also in part.

HANFORD SERIES. These are derived from a great vari-

ety of rock material deposited as river and delta plains. Some even consist of mining debris. They are generally light gray to buff in color, but become dark drab, brown, or black in low areas. The surface is generally level or slightly sloping, and is frequently marked by sloughs or interlacing channels of streams. They occupy a lower topographical position than the Fresno series and are of more recent origin, and some of the members are subject to overflow. They do not have the ashy subsoil or white hardpan of the Fresno series.

SANTIAGO SERIES. This series is typical in the Santa Ana area, where they occur on a delta plain of very recent origin. This delta plain was built up by material brought by the Santa Ana River and Santiago creek in times of flood, and by an elevation of this part of the coast. The river has wandered over this delta, covering it with alternating sandy soils, running in lines parallel to the ocean. The soils are sandy and occupy some of the higher elevations of the delta, and have a subsoil that varies from sandy adobe to sandy loam.

GRIDLEY SERIES. This series in the type region at Marysville is usually a little higher than the surrounding soils, on land that varies from level to slightly rolling. The body of the soils are sediments largely reworked by later alluvial agencies. They are reddish brown in color, with loam subsoil, and with few exceptions are free from hardpan. It is an extensive type in Sutter County, *from the Red Bluff Formation* (Pleistocene).

CORNING, KIRKWOOD, and REDDING series are named for type localities in the Red Bluff area. They are all derived from the geologic formation known as the Red Bluff formation, and have a red color. The Redding series carries water-worn gravel, and has a thin heavy subsoil resting on hardpan. They are locally known as "Red Lands" and "Hardpan Lands." They occupy the higher elevations of the Sacramento valley and are gently rolling in character. The Corning series are found on the west side of the Valley and are similar to the Redding series except that the hardpan is absent. The Kirkwood series are formed from the washing or erosion of the above soils and are deposited on the lower valley plains, on local flats and depressions.

THE CAPAY SERIES of the western part of the Sacramento Valley consist of the finer grades of sediment resulting from the

weathering of complex rocks of the Coast Range mountains and deposited over the valley plain, where temporary lakes or pools have been formed during periods of heavy rainfall and flood. They are characterized by a dark gray color, fineness of texture, and are of a heavy plastic character. Owing to the flatness of the surface, the drainage is often deficient.

THE ALVISO CLAY is found near the seacoast, where the tides at times cover the land, as at Elkhorn Slough in the Pajaro Valley. It is a drab plastic clay, growing pickleweeds, tules, saltgrass, etc.

THE GALVESTON CLAY is found around the waters of San Francisco Bay. The surface is flat and only a little above mean sea level. It is traversed by open tidal sloughs and remnants of former drainage channels. It is generally black in color at the surface and brown or yellow below. It originates from the deposition of clay and the finer silt particles in the slack water of the bay and its system of tidal sloughs and marshes.

SACRAMENTO SERIES. These soils consist of recent stream deposits, generally light gray in color, although the siltier soils may be darker. They were deposited from shifting river currents or from relatively stagnant flood waters covering flood plains, and are subject to overflow when not protected by levees.

FEATHER RIVER SERIES. These occur along the bottoms of the Feather, Bear and Yuba rivers, and are of a deep brown color and silty texture. They are subject to overflow and the drainage conditions are not very good.

ALAMO SERIES. These are plains soils of heavy clay loam adobe, and clay adobe, dark red to black in color and underlain by red hardpan. The surface is low and nearly level and when wet is practically a bog.

SANTA RITA SERIES. The type is found in the Livermore area where the alluvium of the valley has a decided swampy character.

STOCKTON SERIES. These consist in part of alluvium and in part of wash from the more elevated soils. The heavier members have been greatly modified by weathering and by the decomposition of organic matter resulting from swamp or marsh conditions. They occupy extensive areas of the lower nearly level plains of the Great Valley traversed by minor foothill

streams. They are generally older than the Hanford series. The lighter members are chocolate color, the heavier members are black or dark brown. They are underlain by heavy loams or clay loams of lighter color, separated from the soil by a thin white calcareous hardpan free from alkali.

SAN JOAQUIN SERIES. The soils of this series are of a prevailing red color, frequently gravelly, both gravel and soil particles consisting of well-worn quartzose material. They are commonly underlain by red or reddish brown indurated clay or sandy layers cemented by iron salts into a fine hardpan. They consist of old sediments deposited in the waters or about the shores of lakes or bays of early Pleistocene age, modified by recent reworking or by alluvial wash. They occupy valley plains extending from the lower foothills down to level valley floors and margins of present stream channels and are generally extensive in area. The natural drainage is restricted by deficient slope and the underlying hardpan.

SPECIAL SOILS. Not classified under residual, colluvial or alluvial.

RIVER WASH. The miscellaneous deposits of sand and gravel found along rivers and creek beds or spreading over inextensive flood plains.

ROUGH STONY LAND. Stony hills or knolls covered by rock outcrop and boulders with varying quantities of sand, loam, and adobe composing the finer portion.

MEADOW SOILS. These comprise the low-lying, flat, poorly drained land of variable texture and origin. Often ot some value for grass or pasture.

PEAT or **MUCK SOILS.** These are composed largely of organic matter in various conditions of decay. The muck is an advanced state of change of the peat.

SANDHILL, DUNESAND, and **COASTAL BEACH SOILS** are deep sands, often of little agricultural value.

LAKE and **MARSH SOILS,** such as those of Butte Valley in the north end of the state, are formed by the drying up of former lakes in an enclosed basin. The soils are loamy and too wet for tillage, and often mucky or peaty. They are valuable where drainage is possible.

TABLE OF CALIFORNIA SOIL CLASSES. The following table of the physical analyses of the various classes of California soils is only tentative and subject to modification as new classes are formed. It gives the average composition of the soils so far as the work has been carried to date. As the work of mapping the soils is extended, these averages will be changed to some extent, and are therefore not fixed and final. They illustrate the differences in composition in a general way.

AVERAGE COMPOSITION OF CALIFORNIA SOILS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Clay	0.4	1.1	1.2	4.5	8.2	40.1	44.1
Clay adobe	0.6	2.2	2.1	6.8	9.4	39.3	39.4
Silty clay adobe	1.1	1.7	1.6	4.0	6.0	52.1	33.4
Silty clay	0.2	0.4	0.5	3.4	3.4	59.6	32.1
Clay loam	0.5	1.5	1.5	9.5	19.7	41.9	26.7
Gravelly clay loam	6.6	10.7	6.9	14.4	9.4	26.1	25.6
Silty clay loam	0.1	0.5	0.6	4.4	10.6	60.3	23.0
Loam adobes	2.4	6.1	4.1	14.7	19.5	28.9	22.8
Stony loam	4.6	7.6	4.9	13.1	15.4	31.2	22.7
Stony clay loam	1.6	5.6	4.5	8.5	17.6	39.4	22.5
Clay loam adobe	1.0	3.2	2.8	9.4	13.2	38.5	21.8
Silt loam	0.3	1.4	1.3	6.8	11.2	60.4	19.3
Loam	0.2	3.9	4.4	17.3	16.7	39.7	17.9
Sandy adobe	1.3	3.9	6.4	16.9	18.9	34.4	17.0
Gravelly loam	5.7	9.9	6.8	17.4	11.3	32.8	14.8
Gravelly fine sandy loam	2.5	6.1	6.8	27.0	21.7	22.7	12.9
Stony sandy loam	7.4	14.7	7.9	11.7	16.9	28.9	12.3
Gravelly sandy loam	8.9	13.2	8.1	16.3	13.3	29.3	10.5
Fine sandy loam	1.0	3.2	4.6	23.4	26.6	28.7	10.4
Sandy loam	3.7	16.1	12.9	24.7	12.5	23.7	10.2
Silty fine sandy loam	0.0	0.2	0.5	14.6	32.8	41.9	9.9
Gravelly sand	25.6	17.8	8.8	14.3	8.8	13.2	8.6
Coarse sandy loam	9.8	29.4	10.7	17.7	6.0	18.3	7.5
Coarse sand	10.9	28.0	16.7	21.4	6.6	7.8	5.1
Loamy coarse sand	8.1	22.3	12.7	21.7	25.8	5.6	3.8
Fine sand	0.4	2.8	4.7	39.3	31.5	16.4	3.8
Sand	1.5	12.7	23.6	37.8	12.6	7.6	3.7
Dune sand	0.0	24.7	46.3	25.2	0.8	1.7	1.6

CHAPTER XV

CALIFORNIA SOILS DESCRIBED BY CLASSES

CLAY SOILS. ADOBE SOILS

In the following general description of the soils arranged by classes, the average physical analysis of each soil is given in the class to which it belongs. At the foot of each table is given the highest, lowest, and average amount of fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt and clay in the soils described.

A careful study of the table will therefore show wherein each soil is modified by local conditions, such as the nature of the subsoil, concerned. These affect the general properties of the soil and show whether it is light or heavy, easy or difficult to drain and cultivate, or whether it is plastic, puddles, etc. The local productiveness of each soil is modified by local conditions, uch as the nature of the sub-soil, where the soil occurs, local topography, climate, etc. The conditions are given in broad outline with each soil and the reader is referred to the annual reports of the U. S. Bureau of Soils for extended local details.

Under the present system of classification the commercial value of the soils can be seen in the field in the character of the soil and from its relation to natural vegetation and artificial crops. It can be mapped independently of a knowledge of the geology of the region, or of the exact chemical and physical character of the soil. It is now possible to map in the field the areas and distribution of the types, leaving the work of geologic origin, and minute differences to be noted by the soil chemist and physicist in their laboratory investigations . The object of a soil survey, whether of an acre or of a county, is to provide an accurate basis for the adaptation of soils to crops.

CORRELATION. The soils of different areas having the same texture and composition, and the same crop value (the local climatic variations being considered), are given the same name, no matter what part of the state they occur in. This simplifies the nomenclature and calls attention to the similarities of soils and to the possibilities of extending industries into new localities. While no attempt is made as yet by the Government to correlate the soils of the different states except in a very general way, certain close similarities are recognized by all: and soil names are carried across the boundaries of a state in adjoining states. The Fresno sand is the equivalent of the Colorado sand in the lower Arkansas Valley and corresponds very closely in texture and crop value to the truck soils of the Atlantic Coast. The Fresno fine sand is the equivalent of the Laurel fine sand of Colorado; the Fresno fine sandy loam, to the Marshall silt loam of Colorado and to the Weber fine sandy loam of Utah; the Maricopa

gravelly loam, to the Bingham gravelly loam of Utah and the Bridger gravelly loam of Oregon; and the Maricopa sandy loam is the equivalent of the Bridger loam of Oregon, etc.

CHANGES IN NAMES. The U. S. Bureau of Soils with increased knowledge of soils gained as the surveys progress have found it necessary to make certain readjustments in the classifications and names. Some of the names that appeared on the soil maps when published were provisional only, awaiting investigation and comparison. These changes in names have been carefully noted to date in each soil description, and should be noted on the government maps where persons have copies.

CLAY

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Alviso	0.0	0.4	0.7	2.3	0.4	52.3	44.5
Dunnigan	0.1	0.5	0.6	2.3	1.1	30.8	64.5
Esparto	0.0	0.3	0.9	5.9	7.6	43.4	41.6
Galveston	0.6	2.0	2.1	6.4	12.1	31.5	45.2
Imperial	0.1	0.5	0.6	3.5	6.3	36.7	49.1
Livermore	0.3	0.8	1.1	6.5	16.3	44.5	30.4
Sacramento	0.0	0.5	0.7	3.4	1.8	41.0	52.7
Sutter	1.1	4.6	4.3	9.9	11.2	29.6	39.2
Tehama	2.1	2.0	1.8	4.9	18.5	34.9	35.5
Yolo	0.0	0.1	0.1	0.9	7.6	50.9	40.4
Willows	0.5	0.4	0.6	3.2	7.4	45.1	43.4
Highest	2.1	4.6	4.3	9.9	18.5	52.3	64.5
Lowest	0.0	0.1	0.1	0.9	1.1	29.6	34.4
Average	0.4	1.1	1.2	4.5	8.2	40.1	44.1

Soils that contain over 50 per cent of silt and clay together are called clay soil if the clay content is over 30 per cent. They vary widely according to the rocks of the drainage district in which they occur, and in the iron and organic matter present. They are the reverse of the sand soils in character, admitting air and water slowly. Heavy, compact and silty, they become plastic and sticky when wet, with a tendency to puddle, and are retentive of moisture. This makes them cold and hard to till. They dry slowly, forming a hard crust, lumps and clods, and crack badly, and are hard on plant roots. The natural drinage is generally deficient on account of the low positions occupied by the soils. On the other hand these soils are rich in plant food, and under-drainage removes excess of moisture and promotes aeration and warmth. There is a point between wetness and dryness where clay soils crumble quite readily and are friable when carefully handled, and they should be tilled only at such a time as far as possible. They suffer from the extremes of both wet and dry weather and are expensive to cultivate. Clay is an extremely fine soft powder produced by the chemical as well as mechanical decomposition of various minerals. It consists of particles from 0.005 to 0.000 millimeters in diameter. When wet, clay swells up into a sticky plastic substance which shrinks in drying to a tough coherent mass. It is very retentive of water, gases, and minerals in solution, and presents such a large surface for the plant rootlets to feed on that the clay soils are sometimes called **strong soils** by the farmer. Clay also acts as a cement which holds the other ingredients together and renders

the soil hard to till. Silicate of alumina is always present in large quantities and serves to flocculate the soil particles. Without clay the sand would collapse into close packed grains as soon as it became dry, and loose tilth would be impossible.

ALVISO CLAY. Mapped in the Pajaro area. Drab, six feet deep. OCCURS on tidal flats. ORIGIN: alluvial. CROPS: Crops of barley have been grown where protected by levees and washed with fresh water.

DUNNIGAN CLAY. Mapped in the Woodland area. Yellow to dark gray or black, three feet deep. SUBSOIL: Yellow or brown clay. OCCURS on long, narrow areas, in depressed or low flat areas. Locally called "Hogwallow land" in Yolo and Colusa districts. ORIGIN: Fine wash from the flood waters of the basin and wash from higher soils. CROPS: Unfit for cultivated crops without underdrainage. Generally alkaline.

CAPAY CLAY. Mapped in the Woodland area. No analysis reported, gray to gray brown, sometimes tinged with red, three feet deep. SUBSOIL: Dense reddish to yellowish brown clay. OCCURS on low ground, flat, broken by sloughs and creeks. ORIGIN: Recent alluvial. CROPS: Grain, hay, alfalfa where well drained; alkali where the drainage is imperfect.

ESPARTO CLAY. Mapped in the Woodland area. Yellow to dark brown, two to three feet, drainage generally good. SUBSOIL: Clay or clay loam. OCCURS on broad slopes approaching the hills; flat to easy slopes. ORIGIN: Recent alluvial. CROPS: Dry farmed to grain, alfalfa, general farm crops, sugar beets; adapted to sorghum, Egyptian corn, peaches, apricots, almonds, figs, grapes.

GALVESTON CLAY. Mapped in the Los Angeles and San Jose area. Black to brownish gray, over six feet deep, often saturated with salt water. SUBSOIL: Blue or black mud, gray or bluish gray silt. OCCURS around San Francisco Bay, on the coast in coastal swamps, in river channels. ORIGIN: Product of lacustrine or swamp deposits derived from the slack waters of tidal flats, sloughs and estuaries, and silt deposited by rivers in flood times, combined with swamp vegetation. CROPS: Owing to the presence of large amount of alkali salts it has no agricultural value under present conditions of drainage.

IMPERIAL CLAY. Mapped in the Imperial and Indio areas. Slate colored, micaceous, six feet. SUBSOIL: A mixture of clay silt and fine sand. OCCURS in low level places, sometimes hummocky. ORIGIN: Mixed sediments from mountains and rivers. CROPS: Too strong in alkali except for the most alkaline resistant crops, such as sorghum, barley, Egyptian cotton, rice.

LIVERMORE CLAY. Mapped in the Livermore area. Dark chocolate brown, thirty to thirty-six inches. SUBSOIL: Gray brown llay loam. OCCURS on valley bottoms, poorly drained. ORIGIN: Colluvial and alluvial. VEGETATION: Valley oak. CROPS: Hay, grain.

SACRAMENTO CLAY. Mapped in the Marysville area. Black, six feet deep. Locally called "Tule Land," water logged. SUBSOIL: Clays or hardpan. OCCURS in slough basins, overflowed areas,

rarely free from standing water. ORIGIN: From material carried in suspension by river flood waters, with annual additions. CROPS: Too expensive and unprofitable to drain under present methods. Often alkaline.

SACRAMENTO HEAVY CLAY. Mapped in the Woodland area. Blue black to drab, six feet, high per cent of organic matter. SUBSOIL: Similar. OCCURS on floor of basins; flat with slight slope. ORIGIN: Wash from higher soil bodies. CROPS: Grain; where protected from overflow adapted to grain, sorghum, Egyptian corn, hay and other forage crops.

SUTTER CLAY. Mapped in the Marysville area. Brown, few inches deep. SUBSOIL: Sticky, yellowish clay. ORIGIN: Material washed from the Marysville Buttes; from the finer material from the weathering of volcanic rocks. CROPS: Grain in wet years.

TEHAMA CLAY. Mapped in the Red Bluff area. Gray brown to yellowish brown; adobe-like when wet; when dry is hard and cracks and checks; thirty-six to forty-eight inches. SUBSOIL: Variable. OCCURS from gently rolling to flat and depressed areas. ORIGIN: Wash from higher lying soils. CROPS: Grazing.

YOLO CLAY. Mapped in the Woodland area. Brown, six feet deep, lacks organic matter. SUBSOIL: Lighter color, silty clay. OCCURS in irregular bodies; gently sloping from streams; low flat areas ORIGIN: Alluvial. CROPS: Barley, alfalfa; adapted to tree fruits, grapes, beets and other field crops.

WILLOWS CLAY. Mapped in the Colusa and Woodland areas. Reddish, yellowish yellowish brown to drab; three to six feet deep; drainage poor. SUBSOIL: Clay, hardpan. OCCURS on nearly level valley plains, depressions, drainage troughs. ORIGIN: Alluvial. CROPS: Grazing. Generally alkaline.

CLAY ADOBES

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Alamo	0.2	3.4	4.2	10.4	8.3	51.9	21.9
Altmont	0.1	0.9	1.4	4.9	10.4	48.1	34.1
Arnold	0.1	2.1	2.3	10.5	4.9	37.4	42.5
Capay	0.2	1.8	2.3	10.9	16.9	44.5	23.2
Daulton	2.0	4.5	2.8	6.7	6.1	25.3	52.7
Diablo	0.3	1.2	1.6	8.4	19.1	38.5	31.0
Dublin	0.1	0.6	0.8	5.6	17.6	30.1	45.0
Hanford	0.5	2.6	2.5	8.5	8.3	41.5	35.8
Media	2.3	7.1	4.8	10.2	10.3	34.7	30.6
Norman	0.4	1.2	1.1	2.8	0.9	55.6	37.4
Pleasanton	1.5	4.5	3.6	10.4	18.6	28.3	33.2
Portersville	1.3	5.0	3.2	5.7	6.7	34.4	43.5
Sacramento	0.0	0.4	0.3	4.0	3.0	46.9	46.3
Salinas gray	1.1	3.6	4.0	10.3	10.6	37.9	30.7
San Joaquin	0.5	2.4	1.8	10.4	11.7	32.0	41.4
Santa Rita	0.0	0.1	0.5	1.9	12.3	43.9	41.3
Sites	0.0	0.8	1.8	5.3	5.9	37.2	49.0
Stockton	0.5	1.0	0.8	4.0	7.8	37.5	48.5
Vallecitos	0.0	0.5	0.5	3.7	21.9	37.8	35.6
Vina	1.5	2.6	2.2	4.3	9.0	33.3	46.9
Willows	0.1	1.2	0.8	3.9	4.7	37.7	55.7
Highest	2.3	7.1	4.8	10.9	21.9	55.6	55.7
Lowest	0.0	0.1	0.3	1.9	0.9	25.3	21.9
Average	0.6	2.2	2.1	6.8	9.4	39.3	39.4

The Mexican "adobe" is an unburnt brick dried in the sun, and in common use in all western regions where the rainfall is small, the name being derived from the Spanish "adobar," meaning to "daub or plaster." The term was naturally applied to the clayey soils suitable for making the "bricks without straw" or burning. All the adobe soils are clay soils that have typical qualities, as shown by a peculiar stickiness, or adhesiveness, when wet, and checking into cubes when dry.

COMMON PROPERTIES: The table shows that they contain from 22 to 36 per cent of clay and 25 to 56 per cent of silt. That is, over 80 per cent of their material consists of the finest particles of which soils are composed. This makes them dense, close and compact; slow to absorb water, but retain water tenaciously; impervious to more water when thoroughly wet; plastic, sticky, or waxy; puddling when wet; tough, heavy and putty-like, and hard to cultivate. They dry out slowly, baking on exposure, and become hard and compact when dry. They expand when wet, and shrink while drying, causing the soil to check and crack. When the sand contents are above normal, and when they are well drained, they become fairly friable. They are generally dark gray in color, with occasional brown grays and black, and occur in irregular bodies at the base of foothills, on low level plains, and in narrow valleys, or in river depressions that are subject to overflow. Most of them are used only for grazing, hay or grain, but with irrigation, drainage and thorough cultivation, are adapted to alfalfa, grain and general farm crops, and locally to vines and fruit trees.

ALAMO CLAY ADOBE. Mapped in the Marysville area. Gray to black, two to three feet deep. SUBSOIL: Red hardpan. OCCURS: Low, subject to overflow. ORIGIN: Sedimentary and alluvial. Pleistocene lake deposits altered and added to by wash from higher land. CROPS: Grazing, hay, grain, some grapes and fruits.

ALTAMONT CLAY ADOBE. Mapped in the Livermore area. Brown to chocolate, three to five feet, sticky when wet but dries loose and friable. SUBSOIL: Yellow brown clay loam. OCCURS on high hills. ORIGIN: Residual, from Tertiary sandstones and shales. CROPS: Grain and hay.

ARNOLD CLAY ADOBE. Mapped in the Modesto-Turlock area. Purplish brown, black to dark gray, fifteen inches to three feet deep. OCCURS on level plains, and covering hillsides. ORIGIN: Lacustrine, and alluvial weathering of andesitic tuff. CROPS: Dry farming and pasture.

CAPAY CLAY ADOBE. Mapped in the Woodland area. Gray to dark brown, three feet deep, variable in texture. SUBSOIL: Clay, yellow to reddish brown. OCCURS: Flat, low levels of the plains. CROPS: Grain and hay. Frequently alkaline.

DAULTON CLAY ADOBE. Mapped in the Madera area. Red, six feet. SUBSOIL: Granitic and quartz rocks. ORIGIN: Residual. CROPS: Grain.

DIABLO CLAY ADOBE. Mapped in the Livermore area. Dark brown or gray to black, contains an excess of lime, twenty-four to

forty inches. SUBSOIL: Bedrock. OCCURS on the Diablo hills and foothills. Fossil oyster shells (**Astiga titan**) are often found on some of the peaks and ridges. ORIGIN: Residual, modified by colluvial from the Tertiary limestones and calcareous sandstones and shales. Small amount of alkali. CROPS: Dry farmed to hay and grain.

DUBLIN CLAY ADOBE. Mapped in the Livermore area. Slate to black color, twelve to fifteen inches deep. SUBSOIL: Black clay. OCCURS on valley bottoms, nearly level, poorly drained. ORIGIN: Colluvial wash from hills. CROPS: Dry farmed to hay and grain.

HANFORD CLAY ADOBE. Mapped in the Sacramento area as Salinas gray adobe. Dark gray to nearly black, considerable fine to coarse sand. SUBSOIL: Sand, clay, volcanic mud flows. OCCURS as irregular bodies, base of foothills, upper valley margins, flat topped tablelands. ORIGIN: From the weathering and breaking down of interstratified beds of Pleistocene clay, ash and volcanic muds, modified by stream wash. CROPS: Grazing, grain, hay. VALLEY PHASES: Three feet deep, gray to black silt. SUBSOIL: Sandy adobe or hardpan, in local depressions and sinks.

MEDIA CLAY ADOBE. Mapped in the Madera area. Red, three to six feet. SUBSOIL: Partially decomposed granitic rock. OCCURS on rolling lands. ORIGIN: Colluvial and alluvial. CROPS: Grazing.

NORMAN CLAY ADOBE. Mapped in the Colusa area. Dark brown to black; moderately friable when moisture conditions are favorable. SUBSOIL: Clay, clay loam, yellowish to bluish. OCCURS in minor depressions of gently sloping valley plains; in narrow valleys in foothills in irregular bodies. ORIGIN: Alluvial from the sediments of intermittent streams, and wash of more elevated soils. CROPS: With irrigation, drainage and thorough cultivation, alfalfa, grain and general farm crops.

PLEASANTON CLAY ADOBE. Mapped in the Livermore area. Dark brown, carries angular gravel, eighteen to thirty-six inches. SUBSOIL: Red yellow clay. OCCURS on hills and narrow ridges. ORIGIN: Sedimentary. CROPS: Grazing, hay.

PORTERSVILLE CLAY ADOBE. Mapped in the Portersville and Madera areas. Black, six feet deep, small rock fragments, lime concretions, locally called "dry bog land," high per cent of organic matter. SUBSOIL: Similar. OCCURS at lower elevations than the Portersville clay loam adobe. ORIGIN: Largely colluvial, wash from the higher slopes. CROPS: Dry farming to grain. Little alkali.

SACRAMENTO CLAY ADOBE. Mapped in the Woodland area. Gray to black, two to three feet deep, poorly drained. SUBSOIL: Dark brown, yellow brown clay. OCCURS on low overflowed flat areas. ORIGIN: Alluvial. CROPS: Pasture and grain.

SALINAS GRAY ADOBE. Mapped in the San Jose and lower Salinas Valley areas. That mapped as Salinas gray adobe in the San Bernardino and Sacramento areas has been reclassified as Hanford clay adobe. Light to dray gray, nearly black, texture variable, one to six feet deep; drainage fair, well supplied with organic matter.

SUBSOIL: Sandy loam, clay loam, hardpan, disintegrated granite. OCCURS on smooth or slightly sloping land, on higher elevations, foothills, in narrow irregular bodies. ORIGIN: Wash from granite hills and shaly sandstones, from Jurassic formations, primarily residual. CROPS: Grain, alfalfa, barley in the lower Salinas Valley; peaches, prunes, grapes at San Jose. Some alkali where poorly drained.

SAN JOAQUIN CLAY ADOBE. Mapped in the Portersville area. Dark red, eighteen inches to six feet. SUBSOIL: Dense red hardpan. OCCURS in low depressions, hog wallow depressions, no drainage. ORIGIN: Lacustrine of Pleistocene age. CROPS: Grazing and dry farming.

SANTA RITA CLAY ADOBE. Mapped in the Livermore area. Dark gray, never puddles but checks to a friable surface easily cultivated, three to six feet. SUBSOIL: Slaty to black heavy clay. OCCURS on flat, poorly drained land, some hog wallows. ORIGIN: On site of a former shallow lake, then a tule swamp. Alkali variable. CROPS: Hay, grain, sugar beets.

SITES CLAY ADOBE. Mapped in the Woodland area. Red brown to gray, eighteen inches to three feet. SUBSOIL: Red clay, white or green calcareous clay, clay loam. OCCURS on rolling, hilly land; steep, dissected by narrow valleys. ORIGIN: Residual and colluvial. CROPS: Pasture, grain, hay.

STOCKTON CLAY ADOBE. Mapped in the Marysville, Modesto-Turlock and Stockton areas. Chocolate browns to blacks, one to five feet deep, drainage deficient. SUBSOIL: Light yellow silty clay. OCCURS in irregular shaped bodies in low level places. ORIGIN: From a great variety of rocks, modified by ancient Pleistocene sediments. CROPS: Alfalfa, grain, forage, vines, fruit trees. Generally free from alkali.

VALLECITOS CLAY ADOBE. Mapped in the Livermore area. Red brown, thirty to thirty-six inches. SUBSOIL: Yellow brown clay. OCCURS on narow ridges and in deep ravines. ORIGIN: Residual, from metamorphic rocks. CROPS: Grazing, hay, grain.

VINA CLAY ADOBE. Mapped in the Red Bluff area. Brown, puddles but friable with tillage, two to six feet. SUBSOIL: Clay loam. OCCURS in broad tracts below terraces; level, overflowed, drainage sluggish. ORIGIN: Alluvial. VEGETATION: Valley oaks, wild oats. CROPS: Grain, adapted to stone fruits.

WILLOWS CLAY ADOBE. Mapped in the Colusa and Woodland areas. Dark chocolate brown, three feet deep, drainage poor. SUBSOIL lighter in texture. OCCURS in irregular shaped, elongated bodies, occupies draws and depressions in valley plains. ORIGIN: Wash from foothills and from other soils. CROPS: Dry farming, When drained, adapted to sugar beets, alfalfa and general farm crops. Apt to be alkaline.

SILTY CLAY ADOBE

KIRKWOOD SILTY CLAY ADOBE. Mapped in the Red Bluff area. Dark gray to black, smooth texture, very sticky, six feet and over. SUBSOIL: Same, lighter textured. OCCURS on level or

gently sloping plains. ORIGIN: Wash from the Red Bluff formation and from adjacent soils. Not extensive or important. CROP: Dry farmed to grain. Fine gravel, 1.1; coarse sand, 1.7; medium sand, 1.6; fine sand, 4.0; very fine sand, 6.0; silt, 52.1; clay, 33.4. This soil, as the name shows, is a clay adobe containing an excess of silt.

CHAPTER XVI

SILTY CLAY.

SILTY CLAYS. CLAY LOAMS. GRAVELLY CLAY LOAMS. CLAY LOAM ADOBES. SILTY CLAY LOAMS. LOAM ADOBES. STONY CLAY LOAMS.

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Pajaro	0.0	0.3	0.6	2.4	1.5	65.3	29.0
Sacramento	0.5	0.9	0.7	4.7	3.8	55.2	33.6
Yolo	0.0	0.1	0.1	3.2	5.0	58.3	33.5
Average	0.2	0.4	0.5	3.4	3.4	59.6	32.1

The silty clays are between the silt loams and the clays in character, there being about the same amount of silt and more clay than in the silt loams, and less of the fine sands. They are smooth and vary from light to heavy texture. Being compact, they puddle when wet and bake and check on drying. When well drained and well cultivated, they break into a friable loam and become mellow. They are easily cultivated if worked at the most favorable time so far as their moisture contents are concerned.

PAJARO SILTY CLAY. Mapped in the Pajaro area. Light yellow or drab, high per cent of humus; twelve to thirty-six inches. SUBSOIL: Dark loam, silt loam. OCCURS in old channels, in low depressions, in river bottoms. ORIGIN: From weathered shales deposited by flood waters of streams. CROPS: Adapted to many farm crops; wheat, barley, sugar beets, beans.

SACRAMENTO SILTY CLAY. Mapped in the Colusa and Woodland areas. Black to dark gray; six feet. SUBSOIL: Light colored silty and sandy sediments, heavy clay adobe. OCCURS in irregular, elongated bodies, nearly level. ORIGIN: Old stream flood plains sediments, mixed with wash from adjacent soils. CROPS: Dry farming and grain, wheat, barley; with artificial drainage and intensive cultivation, adapted to sorghum, broom corn, Egyptian corn, alfalfa and sugar beets Sometimes alkali is found in the large depressions.

YOLO SILTY CLAY. Mapped in the Woodland area. Chocolate brown, good drainage, three to six feet. SUBSOIL: Brown clay loam, clay. OCCURS: Flat or slightly undulating along creek courses. ORIGIN: Alluvial. CROPS: Grain, alfalfa, wine and raisin grapes; adapted to sugar beets, sorghum, Egyptian corn, vegetables, etc.

CLAY LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Arbuckle	1.6	3.4	2.9	9.2	11.3	45.9	25.8
Capay	0.2	1.8	2.3	10.9	16.9	44.5	23.2
Daulton	1.5	1.9	1.9	11.3	34.0	24.3	25.2
Dublin	1.3	2.4	1.7	11.6	10.7	47.7	24.4
Esparto	0.0	1.1	3.1	12.7	11.4	40.8	30.3
Fresno	0.4	2.3	2.5	8.0	22.1	40.4	24.2
Gila	0.0	0.6	1.1	6.0	11.9	42.2	37.5
Hanford	0.2	0.7	0.5	6.9	18.1	46.3	27.0
Imperial	0.2	0.2	0.2	3.2	7.6	48.1	35.7
Lewis	0.7	2.3	1.9	8.3	14.4	49.8	22.3
Livermore	0.4	1.5	1.6	9.9	21.8	41.1	23.7
Madera	0.8	4.5	3.7	10.1	11.7	40.6	28.2
Marcuse	0.2	3.0	3.5	14.4	14.5	41.3	23.1
Oxnard	0.3	1.0	1.1	13.9	18.7	36.9	21.7
Placentia	0.2	0.7	0.6	4.1	21.6	43.9	28.8
Sacramento	0.3	0.8	0.5	2.5	6.3	40.3	49.7
San Joaquin	1.9	4.9	3.6	10.7	24.6	29.1	25.2
Sierra	2.7	6.1	3.3	9.0	8.1	41.0	24.1
Stockton	0.1	1.4	1.3	12.1	14.5	48.3	21.8
Tassajero	0.0	0.2	0.9	10.4	28.8	33.3	26.4
Vina	0.4	1.0	1.4	7.3	22.3	47.9	19.2
Willows	0.0	0.5	0.8	9.3	15.0	47.4	26.9
Yolo	0.0	1.9	3.9	16.6	16.6	42.1	19.0
Highest	2.7	6.1	3.9	16.6	34.0	49.8	49.7
Lowest	0.0	0.2	0.2	2.5	7.6	24.3	19.0
Average	0.5	1.5	1.5	9.5	19.7	41.9	26.7

Soils containing 50 per cent of silt and clay are called clay loams. if they contain from 20 to 30 per cent of clay, or less than 50 per cent of silt. The average of the analyses show that the California clay loams contain about 42 per cent of silt and 27 of clay, with nearly 20 per cent of very fine sand and 10 of fine sand. They are rather heavy, being a little heavier than silt loam but not so heavy or sticky as adobe, yet stiff and compact. They do not crack when dry in the manner true adobe does. They readily absorb and retain water and are sticky and tenacious when wet. The clay loams require very heavy farm equipment, the cultivation being limited to a somewhat narrow range of moisture conditions. On the other hand, they are friable and mellow and easily cultivated under favorable moisture upon local conditions of drainage, climate and careful management. conditions such as when well drained. They are apt to contain alkali in spots, especially in low poorly drained areas, and are to be feared on this account more than the other loams. The crop depends

ALTAMONT CLAY LOAM. Mapped in the Livermore area. Dark brown, carries fragments of shale, 18 to 30 inches. SUBSOIL: Yellow clay loam. OCCURS on steep hills. ORIGIN: Residual from shales. VEGETATION: Live oak, poison oak, maple, shrubs. CROPS: Grazing, hay, grain.

ARBUCKLE CLAY LOAM. Mapped in the Woodland area. Brown or gray brown; 24 to 36 inches deep, small percent of gravel; drainage variable. SUBSOIL: Yellowish brown clay loam; clay. OCCURS in large irregular bodies, on flat to gentle slopes. ORIGIN: from the deposits of finer material carried by the foothill streams,

modified by later wash from the more elevated surrounding soil bodies. CROPS: Wheat, barley, wine and raisin grapes; hardy fruits; general farm crops; dairy farming.

CAPAY CLAY LOAM. Mapped in the Woodland area. Gray to brown, six feet deep, contains fine gravel, well drained. SUBSOIL: Heavy, red brown clay. OCCURS along small intermittent streams. ORIGIN: Recent alluvial. CROPS: Grain, almonds, grapes. Free from alkali where well drained.

DAULTON CLAY LOAM. Mapped in the Madera area. Brown, two to six feet. SUBSOIL: Quartz, schist, granitic rocks. OCCURS on rolling foothills. ORIGIN: residual. CROP: Grain.

DUBLIN CLAY LOAM. Mapped in the Livermore area, Brown to black, one to four feet. SUBSOIL: Loam. OCCURS on slopes at the foot of hills. ORIGIN: Colluvial and alluvial. CROPS: Dry farmed to grain; irrigated—peaches, pears, prunes.

ESPARTO CLAY LOAM. Mapped in the Woodland area. Yellow to yellow brown; three feet deep. SUBSOIL: Silty clay; clay loam. OCCURS: Marks the position of present or former streams; on narrow or of expansive ridges, slightly elevated above the surrounding level. ORIGIN: Recent alluvial. CROPS: Grain, alfalfa, apricots, peaches, figs, almonds, grapes; adapted to beans, beets and general farm crops. Free from alkali.

FRESNO CLAY LOAM. Mapped in the Madera area. Brown to black, two to six feet. SUBSOIL: Bluish hardpan. OCCURS: Level, marked by sloughs, drainage poor. ORIGIN: Alluvial. Carries some alkali. CROPS: Local—alfalfa, prunes, plums, pears.

GILA CLAY LOAM. Mapped as Imperial loam in the Yuma California area. Chocolate brown, three to six feet deep; contains considerable organic matter. SUBSOIL: Sand, clay. OCCURS: Generally level, in bottom lands, above overflow and quite well drained. ORIGIN: Deposited directly from river waters. CROPS: Under careful management should prove valuable for cereals, and such summer annuals as Kaffir, Egyptian, and Indian corn, millet, sorghum and all crops not requiring intertillage. Contains from 0.2 to more than 3 per cent alkali, hence more to be feared than others of the series.

HANFORD CLAY LOAM. Mapped in the Madera area. Mapped as Santiago silt loam in the San Bernardino and San Gabriel areas; and as Oxnard silt loam in the Bakersfield area. Chocolate brown to black; contains high per cent of organic matter, three to six feet deep. SUBSOIL: Sand, fine sandy loam. OCCURS: Level, low flat tracts cut by sloughs and remnants of former stream channels. ORIGIN: Alluvial. CROPS: Alfalfa, grain, small fruits. Generally free from injurious quantities of alkali.

IMPERIAL CLAY LOAM. Mapped as Imperial loam in the Imperial area. Reddish, contains considerable organic matter. SUBSOIL: Clay loam; clay. OCCURS: Smooth and level. ORIGIN: River sediments deposited while the area was submerged, or from overflow waters. CROPS: Adapted to wheat, barley, sugar beets, Kaffir corn, Egyptian corn, sorghum, alfalfa if not pastured. Generally some alkali, heavy in spots.

LEWIS CLAY LOAM. Mapped in the Portersville area. Grayish, six feet deep; poorly drained. SUBSOIL: Gravel, hardpan. OCCURS in long narrow strips, uneven, lowland. ORIGIN: Alluvial, fine sediments deposited by creeks in body of quiet water. CROPS: Grazing only. Alkali always present.

LIVERMORE CLAY LOAM. Mapped in the Livermore area. Gray brown, bakes, checks, three to four feet. SUBSOIL: Yellow brown clay loam. OCCURS: Level, well drained. ORIGIN: Colluvial and alluvial. VEGETATION: Valley oak. CROP: Grain, grass.

MADERA CLAY LOAM. Mapped in the Madera area. Brown, three to six feet. SUBSOIL: Red hardpan. OCCURS along the smaller stream courses. ORIGIN: Colluvial and alluvial. CROPS: Grain, adapted to fruit locally.

MARCUSE CLAY LOAM. Mapped in the Marysville area: Gray to black, two to three feet deep. SUBSOIL: Reddish, sticky loam. ORIGIN: Alluvial, deposited by overflow waters. CROPS: Grazing during dry season. Alkali generally present in dangerous quantities.

OXNARD CLAY LOAM. Mapped as Oxnard loam in the Los Angeles, San Jose and Ventura areas. Dark brown to black, two to ten feet, rich in organic matter, generally well drained. Stony phase contains gravel, slate fragments and granitic pebbles. SUBSOIL: same but heavier and more compact; gravelly soil. OCCURS: Gently sloping plain, in irregular-shaped bodies; level, on slightly depressed parts of valleys. ORIGIN: From slate and argillaceous sandstone and closely allied rocks; a mixture of the lighter soils derived from mountain waste, with the heavier alluvial and lacustrine deposits of the valley. CROPS: Lima beans, alfalfa, fruit, barley, corn, truck, grapes, strawberries, raspberries, onions, tomatoes, walnuts, lemons. Alkali present in appreciable quantities in low and poorly drained areas.

PLACENTIA CLAY LOAM. Mapped as Placentia loam in the San Bernardino area. Reddish brown, micaceous, six feet deep, considerable fine sand, poorly drained. OCCURS: Level, smooth. ORIGIN: Washings from the Placentia sandy loam. CROPS: Alfalfa. Some alkali due to seepage.

SACRAMENTO CLAY LOAM. Mapped in the Stockton area. Dark to black, high per cent of organic matter, two to thirty feet deep, drainage poor. SUBSOIL: Light yellow, fine silty loam, fine sandy loam. OCCURS: Level, slightly inclined, grades into peats, adobes and loams. ORIGIN: River silts mixed with alluvial organic matter of the tidal fresh water marshes. CROPS: Alfalfa, redtop, rye grass, timothy, wheat, barley, oats, beans, vegetables, grains; peaches, apricots, pears and cherries where well drained. Generally free from alkali.

SAN JOAQUIN CLAY LOAM. Mapped in the Madera area. Red to red brown; two to four feet. SUBSOIL: Red hardpan. OCCURS: In small local areas, hogwallows. ORIGIN: Colluvial and alluvial. CROP: Grain.

SIERRA CLAY LOAM. Mapped in the Sacramento area. Light to deep red; three feet deep, drainage good. SUBSOIL: Bedrock. OCCURS: Prevailing type of the upper foothill region in the Sacramento area; outcropping ledges. ORIGIN: Weathering in place of underlying amphibolite diabase and limestone. CROPS: Grains, hay,

grapes; deciduous fruits; olives. NATIVE VEGETATION: Oak, gray leaf and yellow pine, shrubs.

STOCKTON CLAY LOAM. Mapped in the Modesto-Turlock area. Yellow, 18 to 24 inches deep. SUBSOIL: Yellow adobe, silty fine sandy loam, hardpan. OCCURS: Smooth, flat, gently sloping flood plains. ORIGIN: Deposited by local streams. CROPS: Grain farming, alfalfa, grapes, adapted to peaches, prunes, figs, berries and garden truck. Free from alkali.

TASSAJERO CLAY LOAM. Mapped in the Livermore area. Dark brown, three feet. SUBSOIL: Same, lighter colored. OCCURS on valley floor, well drained. ORIGIN: Colluvial and alluvial. CROPS: Hay, grain, peaches, prunes, apricots.

VINA CLAY LOAM. Mapped in the Red Bluff area. Brown; puddles but is friable with tillage; two to six feet. SUBSOIL: Clay loam or loam, or volcanic conglomerate. OCCURS in broad tracts, below terraces, level, marked by abandoned water channels, overflowed, drainage sluggish. ORIGIN: Alluvial. VEGETATION: Valley oaks, wild oats. CROP: Grain, adapted to stone fruits.

WILLOWS CLAY LOAM. Mapped in the Colusa and Woodland areas. Chocolate brown, yellow, three to six feet deep; drainage poor. SUBSOIL: Reddish brown, heavy, compact clay loam. OCCURS: Occupies nearly flat depressions and low ridges of the valley plain. ORIGIN: Wash from slopes; deposits from small foothill streams. CROPS: Dry farming, pasture, alfalfa, grapes. When well drained is well adapted to alfalfa, sugar beets, wine, table and raisin grapes, and general farm crops. Generally free from alkali. NATIVE VEGETATION: Willows.

YOLO CLAY LOAM. Mapped in the Woodland area. Light to chocolate brown; three feet deep, well drained. SUBSOIL: Heavy clay loam. OCCURS: Flat to undulating along the side slopes of stream courses. ORIGIN: Alluvial. CROPS: Barley, wheat, hay, alfalfa, beets, garden truck, wine and raisin grapes.

GRAVELLY CLAY LOAM

PLEASANTON GRAVELLY CLAY LOAM. Mapped in the Livermore area. Dark brown, 15 to 30 inches. SUBSOIL: Yellowish red to brown. OCCURS on rough ridges and in deep ravines. ORIGIN: Residual. CROPS: Grazing. PHYSICAL ANALYSIS: Fine gravel, 6.6; coarse and, 10.7; medium sand, 6.9; fine sand, 14.4; very fine sand, 9.4; silt, 26.1; clay, 25.6.

SILTY CLAY LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Elder	0.1	0.2	0.4	5.9	17.1	56.6	19.5
Gridley	0.0	0.3	0.3	2.6	7.7	64.1	24.9
Maywood	0.4	1.0	1.4	6.8	8.5	58.5	22.9
Sacramento	0.0	0.2	0.3	6.4	14.5	61.5	17.3
Santa Rita	0.5	1.4	1.4	4.0	5.7	60.3	26.4
Willows	0.0	0.2	0.1	0.9	10.1	60.9	27.0
Highest	0.5	1.4	1.4	6.8	17.1	64.1	27.0
Lowest	0.0	0.2	0.1	0.9	5.7	56.6	17.3
Average	0.1	0.5	0.6	4.4	10.6	60.3	23.0

Soils that contain over 50 per cent of silt and clay are called silty clay loam, if they contain 20 to 30 per cent clay and over 50 per cent silt. They contain more of the fine sands than the silty clays and are therefore more friable, and not so liable to check and bake, and are easily tilled. They are compact and somewhat sticky and heavy when wet, and check some when dry; yet they rarely puddle and are friable under cultivation.

ELDER SILTY CLAY LOAM. Mapped in the Red Bluff area. Gray, rich in organic matter, 24 to 30 inches. SUBSOIL: Heavy loam. OCCURS along creek bottoms. ORIGIN: Alluvial. CROPS: Grain, alfalfa.

GRIDLEY SILTY CLAY LOAM. Mapped in the Marysville area. Dark reddish brown, without drainage. SUBSOIL: Black, heavy, clay loam, calcareous hardpan. OCCURS in irregular areas, lower than surrounding soils. ORIGIN: Alluvial. CROPS: Grain, pasture; adapted to alfalfa, grapes, etc., when drained.

MAYWOOD SILTY CLAY LOAM. Mapped in the Red Bluff area. Smooth texture, very compact, cracks on drying, six feet. SUBSOIL: Same, lighter texture. OCCURS on plains, poorly drained. ORIGIN: Reworked alluvial. CROPS: Peaches, figs, pears, alfalfa.

SACRAMENTO SILTY CLAY LOAM. Mapped in the Colusa, Red Bluff and Woodland areas. Dark gray to dark brown, micaceous, well drained, six feet. SUBSOIL: Same to clayish. OCCURS in narrow areas, level flood plains, lower draws, lower hill slopes, marked by sloughs. ORIGIN: Alluvial. CROPS: Sugar beets, prunes, citrus, sorghum, alfalfa, hops, fruit, truck. One of the most productive soils of the Colusa area.

SANTA RITA SILTY CLAY LOAM. Mapped in the Livermore area. Dark gray, two to three feet. SUBSOIL: Same, of lighter color and texture. OCCURS on low flat land, marked by abandoned drainage channels. ORIGIN: Originally swampy, but now naturally drained. CROPS: Grain, hay, alfalfa, truck.

WILLOWS SILTY CLAY LOAM. Mapped in the Colusa area. Ashen gray, three to six feet. SUBSOIL: Brown, yellowish red, or reddish brown clay loam. OCCURS in irregular bodies, on the lower portions of the nearly level plains. ORIGIN: Alluvial. CROPS: Grazing, dry farming; when drained, adapted to alfalfa, sugar beets. Alkali in minor spots.

LOAM ADOBES

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Placentia	0.7	1.9	2.3	14.0	26.8	30.5	21.5
Sierra.	6.0	13.4	7.0	15.1	10.2	25.4	21.1
Stockton	0.5	3.0	3.2	15.2	21.6	30.8	25.9
Average	2.4	6.1	4.1	14.7	19.5	28.9	22.8

The loam adobes contain less silt than the clay or sandy adobes, and a higher percent of the coarser sands. They possess a better balanced quantity of the various sands than any of the other adobes. While they are sticky and plastic they respond readily to draining

and high cultivation and become favorite soils for grapes, and locally for walnuts, citrus, olives, grapes and general fruits.

PLACENTIA LOAM ADOBE. Mapped as Fullerton sandy abode in the Los Angeles and Santa Ana areas. Locally called "Foothill soil" at Santa Ana. Brown to dark brown, three feet deep. SUBSOIL: A lighter phase of the soil, yellowish gray indurated sand, sandy loam, sand, gravel, shaly sandstone. OCCURS: Rolling hills, sloping plains, foothills. CROPS: Walnuts, beans, grains, wheat, barley, citrus at Whittier, olives at Mirada, a great grain soil in southern California. Generally free from alkali.

SIERRA LOAM ADOBE. Mapped as Sierra loam in the Sacramento area. Dark red, six inches to six feet deep. SUBSOIL: Residual red adobe. OCCURS on gently rolling slopes to steep rugged hill, rock outcrops, boulders. CROPS: Hay, grain, grapes and fruit.

STOCKTON LOAM ADOBE. Mapped in the Stockton area. Black, thirty inches. SUBSOIL: Yellow, silty, clay loam. OCCURS: Level, low positions. ORIGIN: Lacustrine, modified by stream sediments. CROPS: Hay, grain, alfalfa, forage, grazing. Locally alkaline in spots.

STONY LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Sierra	5.3	9.3	4.9	14.5	10.8	32.3	22.4
Tuscan	4.0	6.0	4.9	11.8	20.0	30.1	23.1
Average	4.6	7.6	4.9	13.1	15.4	31.2	22.7

SIERRA STONY LOAM. Mapped in the Sacramento area. Brown to black, six to thirty inches. SUBSOIL: Volcanic gravels, muds and breccia. OCCURS in irregular-shaped bodies, on summits of flat-topped volcanic ridges and knobs, surface strewn with boulders. ORIGIN: Residual, the decomposition of andesitic boulders and the volcanic muds and breccias. VEGETATION: Gray leaf pine, shrubs. CROPS: Grazing.

TUSCAN STONY LOAM. Mapped in the Red Bluff area. Gray, very variable in texture, porous, leachy, 18 to 72 inches. SUBSOIL: Cemented volcanic material. OCCURS on level to rolling barren plains. ORIGIN: Residual from volcanic flows. CROPS: Sheep range.

STONY CLAY LOAM

VALLECITOS STONY CLAY LOAM. Mapped in the Livermore area. Red brown, 10 to 24 inches. SUBSOIL: Brown clay loam. OCCURS on hills and steep slopes with rock outcrops. ORIGIN: Residual from metamorphic rocks. VEGETATION: Field oak, live oak, buckeye, shrubs. CROPS: Grazing. PHYSICAL ANALYSIS: Fine gravel, 1.6; coarse sand, 5.6; medium sand, 4.5; fine sand, 8.5; very fine sand, 17.6; silt, 39.4; clay, 22.5.

CLAY LOAM ADOBES

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Alamo	1.3	8.1	4.5	9.6	14.2	41.9	20.2
Danville	0.0	0.6	1.3	6.7	27.6	36.9	27.2
Dublin	0.0	0.4	1.4	16.0	24.9	27.3	30.1

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Oxnard	0.9	3.2	2.1	7.6	10.8	36.0	35.4
Pajaro	0.0	0.5	0.2	4.6	12.6	55.5	27.0
Placentia	2.8	3.1	7.1	24.5	31.1	19.6	8.8
Portersville	4.3	8.4	4.1	7.8	6.8	32.3	36.1
San Joaquin	1.4	3.1	1.3	4.9	9.5	44.8	35.1
Sites	0.0	3.6	5.0	16.3	12.5	36.8	25.7
Sutter	1.0	5.1	4.3	14.2	8.0	41.7	25.8
Stockton	0.6	1.9	3.0	8.3	14.5	42.6	27.9
Watsonville	0.2	0.8	0.9	12.3	16.9	46.6	22.1
Lowest	0.0	0.4	0.2	4.6	6.8	19.6	8.8
Highest	4.3	8.4	5.0	16.0	31.1	55.5	36.1
Average	1.0	3.2	2.8	9.4	13.2	38.5	21.8

The clay loam abodes are similar to the loam adobes except in the larger percent of clay and silt. This makes them heavy and dense, and causes them to absorb and hold large quantities of water. They are hard to plow when dry and break up into clods. They are fairly easy to cultivate if well drained and not too wet. When too wet they become waxy and sticky and puddle, and bake and crack on drying. They are rich in plant food and have a higher agricultural value than the other adobes. These soils were formerly given up wholly to grain, hay, and grazing, but their value is now appreciated and drainage and proper handling is adding every year to their reputation for special crops.

ALAMO CLAY LOAM ADOBE. Mapped in the Marysville area. Dark reddish brown to red, 12 to 30 inches deep. SUBSOIL: Dense hardpan. OCCURS in low positions, level, hog wallows, poorly drained. ORIGIN: Alluvial wash. CROPS: Pasture, sown to hay, adapted to Tokay grapes, etc.

DANVILLE CLAY LOAM ADOBE. Mapped in the Livermore area. Brown to black, carries some shale and angular rock fragments, 24 to 36 inches. SUBSOIL: Clay loam. OCCURS on valley floor. ORIGIN: Colluvial and alluvial. CROPS: Dry farmed to grain, deciduous fruits do well under irrigation.

DUBLIN CLAY LOAM ADOBE. Mapped in the Livermore area. Brown to black, carries shale fragments, 18 to 48 inches. SUBSOIL: Yellow clay loam. OCCURS on valley bottom and sides. ORIGIN: Colluvial and alluvial. CROPS: Dry farmed to hay and grain.

OXNARD CLAY LOAM ADOBE. Mapped as San Joaquin black adobe in the Los Angeles, Lower Salinas Valley, San Bernardino, San Gabriel, Santa Ana and Ventura areas. Black to dark brown, three to six feet, usually well drained. SUBSOIL: Shale, shaly sandstone, sandy loam, sand, gravel. OCCURS along river beds, capping shaly hills, on level valley floors, low rolling hills, slough and lake bottoms. ORIGIN: Weathering of argillaceous sandstones and shale in place, or the washings from them. CROPS: Grain, alfalfa, corn, barley. Generally free from alkali.

PAJARO CLAY LOAM ADOBE. Mapped in the Pajaro area. Black, high percent of lime and humus, poorly drained, apt to be water-logged, naturally very fertile, three feet deep. SUBSOIL: Compact clay loam, or silty clay loam. OCCURS on low elevations along rivers. ORIGIN: Composed of weathered shale, the finer or clay

particles of which were deposited in quiet waters. CROPS: Apples, alfalfa, strawberries, loganberries, raspberries, blackberries, sugar beets, beans, onions, barley.

PLACENTIA CLAY LOAM ADOBE. Mapped as Sierra adobe in the Fresno area. Reddish. SUBSOIL: Same. OCCURS: Foothills, steep land. ORIGIN: Normal product of the weathering of the granitic rocks of the foothills. CROPS: Dry farming.

PORTERSVILLE CLAY LOAM ADOBE. Mapped in the Portersville area. Dark brown, two to six feet deep, carries subangular fragments. SUBSOIL: Reddish brown to almost white, marly. OCCURS: Locally called "Dry bog adobe," found on the outer slopes of the foothills of the Coast Range, quite steep. ORIGIN: Residual, from weathering and decomposition of the underlying granitic rocks, which are associated with magnesite and lime. CROPS: Formerly to grain, especially adapted to oranges and lemons. Free from alkali.

SAN JOAQUIN CLAY LOAM ADOBE. Mapped as San Joaquin red adobe in the Sacramento area. Red, two to three feet. SUBSOIL: Red sandy hardpan. OCCURS: Lower slopes of the valley plains, smooth. ORIGIN: Alluvial. CROPS: Grain and hay.

SITES CLAY LOAM ADOBE. Mapped in the Colusa and Woodland areas. Reddish to gray browns, six feet deep, gravelly. SUBSOIL: Silt, red clay, clay loam adobe, red clay hardpan, gravelly loam, cemented gravel. OCCURS on lower undulating foothills of the Coast Range. ORIGIN: Weathering from sandstone, shale and conglomerate. CROPS: Dry farmed, grazing, grain.

SUTTER CLAY LOAM ADOBE. Mapped in the Marysville area. Chocolate brown, two to three inches. SUBSOIL: Same, lighter brown. OCCURS in irregular-shaped small bodies in the smaller valleys. ORIGIN: Wash from the volcanic rocks of the Marysville Buttes, and from adjacent soils. CROPS: Grain cut for hay.

STOCKTON CLAY LOAM ADOBE. Mapped in the Stockton area. Mapped as San Joaquin black adobe in the San Jose, Hanford and Fresno areas. Locally called "Dry bog soil." Black, three to six feet deep, poorly drained. SUBSOIL: Yellow, heavy silty or silty clay hardpan. OCCURS on low level flat plains, lower levels or depressions of valley floor. ORIGIN: Old lacustrine or swamp deposits modified. CROPS: Alfalfa, wheat, rye, barley, forage grass, vegetables, flower seeds, strawberries, raspberries, sugar beets, apples, pears prunes at San Jose and Santa Clara. Generally free from alkali.

WATSONVILLE CLAY LOAM ADOBE. Mapped in the Pajaro area. Black to dark brown, 20 to 30 inches deep. SUBSOIL: Yellow, gritty clay loam. OCCURS: Lowest hills and their slopes adjacent to the river. ORIGIN: Residual from decomposing shales. CROPS: Grains, pears, eucalyptus.

CHAPTER XVII

SILT LOAMS. LOAMS.

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Feather	0.0	0.2	0.2	0.7	4.2	81.1	13.4
Gila	0.5	0.3	0.3	2.7	10.3	54.8	31.3
Hanford	0.2	0.8	0.7	5.5	13.3	58.0	19.5
Marysville	0.0	0.8	0.5	5.2	13.7	57.1	22.6
Maywood	1.6	2.2	1.9	9.5	11.3	57.3	15.9
Oxnard	0.0	0.5	0.7	8.1	10.5	55.9	19.9
Pajaro	0.0	0.1	0.1	10.6	22.2	53.3	12.7
Sacramento	0.0	0.6	1.0	8.8	9.6	64.1	16.0
Sites	0.5	3.1	3.2	6.0	8.6	60.5	18.1
Stockton	1.0	6.6	6.0	16.7	15.3	53.5	18.8
Yolo	0.0	0.1	0.1	1.2	5.0	69.1	24.4
Highest	1.6	6.6	6.0	16.7	22.2	81.1	24.4
Lowest	0.0	0.1	0.1	0.7	4.2	53.3	12.7
Average	0.3	1.4	1.3	6.8	11.2	60.4	19.3

When soils contain over 50 per cent of silt and clay they are called silt loams, if they contain less than 20 per cent clay or over 50 per cent silt. They are finer than the fine sandy loams, and the particles are very uniform in size. They are fine, close, and dense in texture, retentive of moisture; very sticky and liable to puddle if plowed when wet, but loose and friable when dry. If plowed when too dry, they form large hard clods. Under cultivation they break into a fine friable loam. They are generally rich in organic matter.

ELDER SILT LOAM. Mapped in the Red Bluff area. Gray, smooth, friable, six feet. SUBSOIL: Coarse alluvium. OCCURS as broad alluvial bottoms, well drained. ORIGIN: Alluvial. CROPS: Dry farmed to grains, adapted to prunes, peaches, wheat, barley, alfalfa, sugar beets, melons, truck.

FEATHER SILT LOAM. Mapped in the Marysville area. Light to dark brown, shale particles, six feet. SUBSOIL: Similar but heavier. OCCURS in river bottoms. ORIGIN: Alluvial deposited by creeks, subject to annual overflow. Locally called "Black Land." CROPS: Alfalfa, corn, sorghum; adapted to truck crops and small fruits.

GILA SILT LOAM. Mapped as Imperial silt loam in the Yuma-California area. Mapped as Santiago silt loam, Yuma area. Gray to brown, poorly drained, 12 to 30 inches. SUBSOIL: Sand, loam, clays. OCCURS on lands overflowed by annual river floods, in low places, comparatively level, in long strips. ORIGIN: Sediments deposited after the river floods have been robbed of their fine sand. CROPS: Kaffir, Egyptian and Indian corn, Milo maize, millet, sorghum, garden vegetables, melons, pumpkins. Often free from alkali.

HANFORD SILT LOAM. Mapped in the Modesto-Turlock area. Mapped as Santiago silt loam in the Los Angeles, Lower Salinas Valley areas. Mapped as Sacramento silt loam in the Sacramento area,

and mapped as Fresno fine sandy loam in the San Jose area. Brown to black, yellowish to gray, micaceous, very sticky, two to six feet, wet and poorly drained in places; light colored are friable and the dark colored are heavy. SUBSOIL: Sand, silt, brown or dark clay loam, lighter sediments. OCCURS in long narrow strips in irregular-shaped bodies, on flat plains, river terraces, in slight depressions, level, locally subject to overflow. ORIGIN: Alluvial, deposited along stream flood plains and in depression by slack silt-laden waters. CROPS: Alfalfa, strawberries, raspberries, beans, potatoes, sugar beets, hops, asparagus. Generally small amounts of alkali near the surface, heavy locally.

MARYSVILLE SILT LOAM. Mapped in the Marysville area. Light brown, poorly drained, overflowed, 18 inches to 4 feet. SUBSOIL: Reddish brown sticky silty clay loam, gray hardpan. OCCURS at junction of streams subject to floods. ORIGIN: Alluvial. CROPS: Where drainage is possible, alfalfa, grapes, stone fruits.

MAYWOOD SILT LOAM. Mapped in the Red Bluff area. Yellowish gray, smooth texture, compact, sticky when wet, friable when properly handled, uniform, 30 to 36 inches. SUBSOIL: Silty clay loam. OCCURS along minor streams. Drainage adequate. ORIGIN: Alluvial. VEGETATION: Oaks, willows. CROPS: Dry farming, orchards.

OXNARD SILT LOAM. Mapped in the San Jose and Ventura areas. That mapped as Oxnard silt loam in the Bakersfield area has been reclassified as Hanford clay loam. Brownish, well drained; heavier phases resemble true adobe. OCCURS in bodies of irregular outline, between valley bottoms and base of mountains, slightly undulating, level, smooth plains. ORIGIN: Deposition of finer particles held in suspension by flood waters, disintegrated sandstone mixed with organic matter. CROPS: Very fertile — prunes, apricots, cherries, apples, small fruits, hay, lima beans, walnuts, citrus fruits. Some alkali where drainage is deficient.

PAJARO SILT LOAM. Mapped in the Pajaro area. Brown, smooth, micaceous, three feet. SUBSOIL: Lighter in texture and color, 30 feet. OCCURS parallel to the rivers, scalloped by river floods. ORIGIN: From weathered and transported shales. CROPS: Very fertile; apples, alfalfa, sugar beets, beans, potatoes, strawberries, loganberries, blackberries, raspberries. PHASE: **Light silt loam,** mapped in the Pajaro area, light brown, very micaceous, six feet, similar subsoil. OCCURS: Low lying, occasionally flooded. CROPS: Apples, berries, truck gardening.

SACRAMENTO SILT LOAM. Mapped in the Colusa, Marysville, Modesto-Turlock, Woodland, Red Bluff and Redding areas. That mapped as Sacramento silt loam in the Sacramento area has been reclassified as Hanford silt loam. Light to yellowish brown, dark brown, drab, gray, micaceous, often gravelly, well drained, 18 inches to 20 feet. SUBSOIL: Same, deeper color, compact, sand, gravel. OCCURS: Stream bottoms, in narrow bodies, level. ORIGIN: Alluvial deposited by stream floods. CROPS: Wheat, barley, grapes, alfalfa, hops, broom corn, sugar beets, truck, peaches, prunes, pears. Free from excess of alkali.

SITES SILT LOAM. Mapped in the Woodland area. Yellow to red brown, smooth texture, some water-worn gravel, two feet. SUBSOIL: Dark red loam, clay loam, sandy loam. OCCURS as broad slopes near base of hills. ORIGIN: Residual and colluvial. CROPS: Barley, wheat, with proper cultivation adapted to grapes, almonds, apricots.

STOCKTON SILT LOAM. Mapped in the Stockton area. Light brown, well drained, six feet. SUBSOIL: Lighter colored, more compact, hardpan. OCCURS in large irregular-shaped level bodies. ORIGIN: From a large variety of rocks. CROPS: Vegetables, wheat, barley, oats, alfalfa, root crops, almonds, cherries, peaches, late grapes. Free from alkali.

TEHAMA SILT LOAM. Mapped in the Red Bluff area. Yellow brown to red yellow, puddles, 10 to 20 inches. SUBSOIL: Brown silty clay loam. OCCURS on intermediate plains of gentle slope, poorly drained. ORIGIN: Recent alluvial from Red Bluff formation. CROP: Dry farmed to grain; under irrigation adapted to berry, alfalfa, grapes, farm crops.

VINA SILT LOAM. Mapped in the Red Bluff area. Brown, six feet. SUBSOIL: Volcanic gravel. OCCURS bordering stream channels. ORIGIN: Alluvial. VEGETATION: Oak, cottonwood, willows, sycamore, wild oats. CROPS: Alfalfa, grain, peaches, prunes, grapes, sugar beets, truck.

YOLO SILT LOAM. Mapped in the Woodland area. Light to dark brown, heavy, three feet, good drainage. SUBSOIL: Brown silty clay, loose sandy loam. OCCURS in large irregular-shaped bodies, along sides of creeks, on slopes approaching the ridges along stream channels. CROPS: Dry farmed to grain, well adapted to a wide range of crops if irrigated; alfalfa, sugar beets, garden vegetables, etc.

LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Arbuckle	0.0	0.7	1.2	6.2	23.1	45.6	23.1
Arnold	2.9	12.1	6.7	16.9	7.3	44.2	10.4
Bear	0.2	1.7	1.8	7.6	17.0	49.2	22.4
Corralitos	0.1	3.0	5.4	22.1	5.4	45.2	18.7
Dublin	0.6	2.4	3.9	18.4	31.7	25.3	17.5
Esparto	0.2	1.5	3.1	18.9	21.4	32.6	22.2
Feather	0.0	0.9	1.1	11.2	25.8	45.2	15.9
Fresno	0.4	3.6	3.0	11.2	18.8	40.7	22.1
Gila	0.0	0.3	1.5	15.2	29.4	43.8	9.5
Gridley	0.2	4.4	3.3	13.6	17.1	40.6	20.7
Hanford	1.7	6.1	6.7	17.4	9.6	39.8	18.8
Honicut	0.6	3.9	2.9	13.4	14.0	46.8	18.5
Livermore	0.3	1.2	2.5	15.7	29.9	32.1	18.2
Maywood	1.2	2.4	2.8	13.1	19.3	47.2	13.5
Mocho	2.6	4.0	6.4	20.0	17.7	34.9	14.4
Modesto	1.9	8.8	6.5	18.4	9.9	37.9	16.1
Oxnard	0.8	3.4	3.9	23.0	7.4	42.3	15.4
Pajaro	0.0	0.4	0.4	7.6	19.5	54.8	16.4
Placentia	1.8	4.0	4.8	19.6	10.9	39.6	16.8
Pleasanton	2.9	3.9	3.7	10.2	19.2	44.1	15.8
Portersville	4.0	11.2	9.0	23.9	8.6	22.5	20.8
Redding	4.4	11.4	5.5	13.1	14.4	34.8	16.6
Sacramento	0.9	2.7	3.0	14.9	18.0	45.3	14.4

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Salsipuedes	1.7	6.4	4.9	19.4	10.8	41.0	16.1
San Joaquin	1.8	8.2	5.6	13.5	13.3	40.7	16.5
Santiago	0.0	2.5	1.6	8.8	24.7	43.0	15.9
Santa Cruz	1.1	8.6	8.6	30.1	5.2	23.9	22.0
Santa Rita	0.1	0.6	1.3	6.4	32.2	41.3	17.9
Sierra	3.3	10.6	5.9	11.9	8.9	45.1	14.3
Sites	1.6	3.4	3.1	17.6	20.1	39.1	14.8
Stockton	0.3	6.8	6.0	25.3	15.6	26.5	18.9
Sunol	0.2	0.9	1.7	10.9	15.4	48.3	22.4
Sutter	1.5	5.2	5.4	13.5	11.8	37.9	24.8
Ulmar	0.8	3.0	4.4	13.2	20.8	37.1	20.3
Vallecitos	0.2	2.3	5.9	20.8	28.7	22.7	19.2
Vina	1.4	2.8	3.6	12.5	19.1	45.8	14.8
Watsonville	1.3	6.5	9.3	22.3	11.7	26.9	22.0
Willows	0.9	2.6	2.6	10.6	12.1	44.8	25.9
Yolo	0.1	0.4	0.9	9.5	27.3	43.5	18.2
Highest	4.4	12.1	9.3	30.1	32.2	54.8	25.9
Lowest	0.0	0.3	0.4	6.2	5.2	22.5	9.5
Average	0.2	3.9	4.4	17.3	16.7	39.7	17.9

If soils contain over 50 per cent of silt and clay they are called loam, if they contain less than 20 per cent of clay and less than 50 per cent of silt. They are the most useful all-around soils, combining the lightness and earliness of the sands, with the strength and retentiveness of the clays. They are smooth, uniform, open, porous, and have high capillary power. While naturally compact and liable to be sticky or even puddle when wet, they are loose and powdery when dry and easily cultivated where well drained, and maintain an excellent tilth. They work easily and do not crack or crust. Water moves easily in them and to long distances.

ARBUCKLE LOAM. Mapped in the Woodland area. Light to gray brown. SUBSOIL: Variable in texture, brown sandy loam, loam. OCCURS near present or former streams, sloping, slightly uneven, well drained. ORIGIN: Lacustrine, alluvial. CROPS: Wheat, almonds, raisins, fine grape soil, adapted to alfalfa, fruit, Kaffir and Egyptian corn, sorghum, beets and general farm crops.

ARNOLD LOAM. Mapped in the Modesto-Turlock area. Grayish brown, red, black, mottled, light, sandy, ten to fifteen inches. SUBSOIL: Heavy loam. OCCURS: Covering undulating hills. ORIGIN: Lacustrine, alluvial. CROPS: Dry farming to grain.

BEAR LOAM. Mapped in the Marysville area. Reddish brown, well drained, four to six feet deep. OCCURS: Bottom lands. ORIGIN: Material washed from adjaceint plains soils. CROPS: Grain, hay, alfalfa, stone fruits, grapes, hops.

CORNING LOAM. Mapped in the Red Bluff area. Reddish, slightly sticky, with tendency to clog and puddle, sixteen to thirty inches. SUBSOIL: Clay or clay loam. OCCURS on upland plains, level to gently rolling. ORIGIN: Alluvium from Red Bluff formation. CROPS: Dry farmed to grain. When irrigated it is adapted to peaches, almonds, figs, berries, grapes, etc.

CORRALITOS LOAM. Mapped in the Pajaro area. Chocolate brown, micaceous, three feet deep. SUBSOIL: Brown to yellowish brown micaceous loam, thirty feet deep. OCCURS: Oval-shaped body on higher plain. ORIGIN: Washings from rotten shales from adja-

cent hills, mixed with creek alluvium. CROPS: Generally devoted to grazing, dry farming to grain, apples, apricots, prunes, English walnuts, vegetables, berries, etc.

DUBLIN LOAM. Mapped in the Livermore area. Dark brown to black, two to three feet. SUBSOIL: Gray brown silt loam. OCCURS along creek bottoms. ORIGIN: Colluvial. VEGETATION: Oak, willow, sycamore. CROPS: Dry farmed to hay and grain, adapted under irrigation to fruit, truck, alfalfa.

ESPARTO LOAM. Mapped in the Woodland area. Brown to yellowish brown, well drained, 24 inches. SUBSOIL: Brown clay loam. OCCURS: Moderate elevations near sloughs. ORIGIN: Recent alluvial. CROPS: Excellent grape soil, apricots, almonds, plums, olives, figs, alfalfa. Free from alkali.

FEATHER LOAM. Mapped in the Marysville area. Reddish brown, poorly drained, named for the Feather River; six feet. SUBSOIL: Heavier. OCCURS along river bottoms, flooded. ORIGIN: Alluvial and sedimentary, and subject to alterations by floods. CROPS: Where reclaimed, excellent for alfalfa, peaches, pears.

FRESNO LOAM. Mapped in the Modesto-Turlock and Portersville areas. Mapped as Maricopa loam in the Fresno area. Chocolate to gray brown, red, micaceous, one to six feet. SUBSOIL: Micaceous fine sand, fine sandy loam. OCCURS in low flat tracts, uneven surface, ofter hummocky. ORIGIN: from very fine sediments laid down at former periods by slack water from old river channels, lacustrine. CROPS: Often uncultivated owing to lack of water, dry farming to grain, grazing; adapted to alfalfa, corn, grain, etc., where irrigated. Impregnated in places with soluble alkali salts and common salt.

GILA LOAM. Mapped as Imperial fine sandy loam in the Yuma-California area. Three to twenty feet deep. SUBSOIL: Coarser sand, fine sandy loam. OCCURS in long narrow strips along the Colorado River, smooth, often covered with cottonwood, willow or arrow-weed. ORIGIN: Sediments deposited by river in the annual floods. CROPS: All shallow rooted vines, fruits, vegetables. Sometimes heavy in alkali, but can generally be reclaimed by one year's heavy flooding.

GRIDLEY LOAM. Mapped in the Marysville area. A reddish brown, light, little natural surface drainage, two to six feet. SUBSOIL: Black, clay loam, adobe-like, gray calcareous hardpan. OCCURS: Extensive level plain, surface slightly uneven, contains depressions with no outlet. ORIGIN: Sedimentary altered by river floods. CROPS: Requires drainage ditches; alfalfa, fruits, peaches, pears, apricots, apples, grapes, almonds, figs.

HANFORD LOAM. Mapped in the Portersville area. Dark gray, 28 to 60 inches. SUBSOIL: heavy yellowish or reddish brown loam, light clay loam. OCCURS: Level, no local drainage. ORIGIN: Alluvial material deposited in quiet water. CROPS: Grazing, alfalfa.

HONICUT LOAM. Mapped in the Marysville area. Reddish brown, two feet. SUBSOIL: Dark red loam. OCCURS: Level, well drained. ORIGIN: Alluvial washed from higher soils. CROPS: Truck, alfalfa, berries, figs, stone fruits.

LIVERMORE LOAM. Mapped in the Livermore area. Dark brown, thirty to thirty-six inches. SUBSOIL: Light brown silty loam. OCCURS as strips and irregular bodies on valley floor, level, marked by abandoned stream channels, well drained. ORIGIN: Colluvial and alluvial. CROP: Hay, barley, wheat, grapes, almonds.

MAYWOOD LOAM. Mapped in the Red Bluff area. Grayish or yellowish gray, two to six feet. SUBSOIL: Yellow clay loam. OCCURS on gently rolling valley plains. ORIGIN: Reworked alluvial material. CROP: Dry farmed to grain, adapted to almonds, olives, etc.

MOCHO LOAM. Mapped in the Livermore area. Dark brown to drab, eighteen to twenty-four inches. SUBSOIL: Gray brown sands. OCCURS on level land along creeks. ORIGIN: Alluvial wash from adjacent soils. CROPS: Hay, grain, truck, fruit.

MODESTO LOAM. Mapped in the Modesto-Turlock area. Chocoalte brown, gray, coarse granite sand, twelve inches. SUBSOIL: Clay loam, sandy loam. OCCURS: Uneven, level stretches with hog-wallow depressions, hummocks. ORIGIN: From old overflowed channel deposits. CROPS: Alfalfa, grapes, peaches where drained. Elevated portions free from alkali.

OXNARD LOAM. Mapped in the San Bernardino area. Mapped as Fresno fine sandy loam in the Ventura area. That mapped as Oxnard loam in the San Jose and Ventura areas has been reclassified as Oxnard clay loam. Gray, sticky, micaceous, drainage good, three to six feet deep. SUBSOIL: Dark adobe. OCCURS: Level, smooth, gently sloping plains, hillsides, skirting gullies. ORIGIN: Derived from shale and shaly sandstone, unconsolidated sandstones. CROPS: Pasture, wheat, alfalfa, lima beans, English walnuts, citrus fruits. Free from alkali, where well drained.

PAJARO LOAM. Mapped in the Pajaro area. Dark brown or black, heavy, micaceous, high percent of humus, generous lime content, twelve to eighteen inches. SUBSOIL: Light yellow silt loam, thirty feet deep. OCCURS: Along the lower lands of the rivers and creeks. ORIGIN: Alluvial and sedimentary. CROPS: Apples, alfalfa, sugar beets, beans, potatoes, onions, strawberries, blackberries, loganberries.

PLACENTIA LOAM. Mapped as Placentia sandy loam in the Ventura area. Mapped as Los Angeles sandy loam in the Los Angeles area. That mapped as Placentia loam in the San Bernardino area has been reclassified as Placentia clay loam. Reddish brown to light brown, two to six feet deep. SUBSOIL: Hardpan, decayed rock, yellowish to gray. OCCURS on low rolling hills, steep grades, rough hills. ORIGIN: Disintegration of sandstones and shale in place, wash from sandstone. CROPS: Barley, corn, blackeyed beans, apricots, oranges. Generally free from alkali.

PLEASANTON LOAM. Mapped in the Pleasanton area. Brown, high percent of gravel, sticky, forms surface crust on drying that yields readily to tillage, twelve to thirty inches. SUBSOIL: Reddish clay loam. OCCURS on the lower slopes of the hills. ORIGIN: Sedimentary. VEGETATION: Oaks. CROPS: Wine grapes, adapted to fruit, alfalfa, truck.

PORTERSVILLE LOAM. Mapped in the Portersville area. Grayish red, micaceous, eighteen inches to six feet deep. SUBSOIL: Granitic rock. OCCURS: Granitic foothills and mesas. ORIGIN: Residual, from the underlying granitic rocks, more or less modified by rain wash and alluvial action. CROPS: Dry farming to grain, pasture, citrus fruits. Free from alkali.

REDDING LOAM. Mapped in the Redding area. Light red to reddish gray, eight to twelve inches. SUBSOIL: Dark red, heavy, clay loam, sandy clay hardpan. OCCURS: Upland plains. CROPS: Grazing, wheat, small fruits, table and wine grapes where locally deep.

SACRAMENTO LOAM. Mapped in the Colusa and Redding areas. Light to dark brown, dark gray, drab, three to six feet. SUBSOIL: Sands, gravel. OCCURS in irregular bodies, long narrow areas, level and gently sloping, valley plains, stream bottoms. ORIGIN: Recent, alluvial. CROPS: Alfalfa, beets, grazing, dry farming to grain.

SALSIPUEDES LOAM. Mapped in the Pajaro area. Dark brown, gritty, three feet deep. SUBSOIL: Brown loam, sandy loam. OCCURS: Slope of foothills, valley. ORIGIN: Colluvial from shale, and wash from adjacent hills. CROPS: Apple, prune, apricot.

SAN JOAQUIN LOAM. Mapped in the Colusa, Modesto-Turlock, Marysville, and Stockton areas. Reddish to yellowish gray, dark red, texture variable, often gravelly, ten inches to three feet. SUBSOIL: Brown to reddish brown, heavy clay loam, yellow to red hardpan. OCCURS on gentle slopes, valley plains, foothills, rolling uplands. ORIGIN: Modified early Pleistocene deposits. CROPS: Grain, with irrigation, alfalfa, fruit, Tokay grapes, general farm crops.

SANTIAGO LOAM. Mapped in the Santa Ana area, three to six feet. SUBSOIL: Sand, gravel. OCCURS: Level to rough and broken. CROPS: Wheat, barley.

SANTA CRUZ LOAM. Mapped in the Pajaro area. Brown, filled with lenticular shale fragments, gritty, thirty inches. SUBSOIL: Yellow or drab silt loam. OCCURS: Higher ridges and slopes along creeks and ravines. ORIGIN: From weathering of shale in place. CROPS: Apples, apricots.

SANTA RITA LOAM. Mapped in the Livermore area. Dark gray to black, three feet. SUBSOIL: Gray silt loam. OCCURS on level land. Drainage good. ORIGIN: Alluvial formed under swamp conditions. CROPS: Hops, sugar beets, alfalfa.

SIERRA LOAM. Mapped in the Marysville area. That mapped as Sierra loam in the Sacramento area is Sierra loam adobe. Red, contains sharp angular rock fragments from the Ione formation. SUBSOIL: Light brown to gray loam. OCCURS: Slopes of the lower foothills of the Sierras. ORIGIN: Mainly residual, but along stream courses partially colluvial, from the weathering of the underlying andesite, amphibolitic rocks, and diabase; and from the Ione formation. CROPS: Citrus fruits and olives where irrigated.

SITES LOAM. Mapped in the Colusa and Woodland areas. Light gray, reddish brown, heavy, well drained, fourteen inches to four feet. SUBSOIL: Light colored argillaceous sandstones, mixed with some

shale, limestone, loams, etc. OCCURS in small irregular patches on summits and slopes of lower foothills. ORIGIN: Colluvial, residual from subsoil materials. CROPS: Grain and grazing, adapted to wide range of crops.

STOCKTON LOAM. Mapped in the Stockton and Modesto-Turlock areas. Chocolate brown to black, micaceous, one to six feet. SUBSOIL: Fine silty or sandy loam. OCCURS in irregular bodies, elongated bodies along streams, foot of terraces, generally level. ORIGIN: Alluvial, resulting from the deposition of heterogenous sediments in ancient lakes or bays and streams, modified by admixture of more recent sediments laid down by existing streams. CROPS: Alfalfa, onions, cabbage, grains, hay, peaches, prunes, walnuts, grapes, garden truck. Generally free from alkali.

SUNOL LOAM. Mapped in the Livermore area. Brown, carries angular rock fragments, twenty-four to thirty-six inches. SUBSOIL: Clay loam. OCCURS as level floor of valley. ORIGIN: Colluvial. CROPS: Hay, grain, fruit and alfalfa under irrigation.

SUTTER LOAM. Mapped in the Marysville area. Grayish, some fine gravel, eighteen inches to six feet. OCCURS: Irregular or sloping lands, below edge of Buttes, in small valleys, sometimes subject to overflow, sometimes a slight hog-wallow surface. ORIGIN: Largely colluvial washed from adjacent buttes and altered by alluvial deposits. CROPS: Pasturage, alfalfa, almonds.

ULMAR LOAM. Mapped in the Livermore area. Brown, fifteen to twenty-four inches. SUBSOIL: Yellow or brown clay, and calcareous hardpan. OCCURS: Level, marked by hog-wallows. ORIGIN: Colluvial and alluvial. CROPS: Hay, grain, grazing, under irrigation adapted to strawberries, alfalfa, truck.

VALLECITOS LOAM. Mapped in the Livermore area. Reddish brown, fifteen to thirty inches. SUBSOIL: Yellow clay loam. OCCURS on rough hills and in deep ravines. ORIGIN: Residual from metamorphic rocks. VEGETATION: Live oak, field oak, buckeye. CROPS: Hay, grain, grazing.

VINA LOAM. Mapped in the Red Bluff area. Locally called "Park Soil." Red brown, two to six feet. SUBSOIL: Gravel. OCCURS on fan-shaped stream deltas, gently sloping, often abrupt terraces. ORIGIN: Part of a dissected plain. VEGETATION: Blue oak, ceanothus, chaparral. CROPS: Grain, berries, melons, peaches.

WATSONVILLE LOAM. Mapped in the Pajaro area. Dark brown to gray, high in humus, twenty inches to four feet. SUBSOIL: Reddish yellow clay loam, hardpan, disintegrated shales. OCCURS: Lower portions of ridges and hills, low hills. ORIGIN: Residual from the underlying shales. CROPS: Grain, apples, raspberries, blackberries, strawberries, pears, grapes.

WILLOWS LOAM. Mapped in the Colusa and Woodland areas. Reddish gray, light red, yellow brown, some sharp sand, generally well drained, ten to eighteen inches. SUBSOIL: Reddish brown clay loam, compact, adobe-like. OCCURS in irregular shaped bodies, sloping valley plains near foothills, uneven, hog-wallow mounds.

ORIGIN: Alluvial, weathering of the sandstones of the foothills. CROPS: Raisin, table, wine grapes, alfalfa, sugar beets, sorghum, Egyptian corn, tree fruits, small fruits. Free from alkali.

YOLO LOAM. Mapped in the Woodland area. Dark brown, two to six feet. SUBSOIL: Silty, or sandy, loam. OCCURS: Plains elevated above surrounding areas, undulating ridges. ORIGIN: Deposited by creek waters. CROPS: Peaches, almonds, prunes, grapes. Rarely contains alkali.

CHAPTER XVIII

SANDY ADOBES

GRAVELLY FINE SANDY LOAMS. STONY SANDY LOAMS. GRAVELLY SANDY LOAMS. GRAVELLY LOAMS.

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Placentia	2.0	4.1	3.7	17.1	17.4	33.9	21.4
San Joaquin	1.1	4.5	12.1	23.2	22.1	23.9	10.5
Sierra	0.9	3.2	3.4	10.3	17.4	45.4	19.3
Average	1.3	3.9	6.4	16.9	18.9	34.4	17.0

As the name indicates, they contain the highest per cent of sand of all the adobes. They contain also the least clay, and some fine gravel and coarse sand. These benefit the soils, making them warmer, lighter, better drained and aerated than the other adobes. They are, however, still compact, sticky, retentive of moisture, heavy and difficult to cultivate, and have a tendency to pack and bake. Under modern methods of intense cultivation they are adapted to citrus and deciduous fruits, berries and truck crops, as they are generally supplied with organic matter, and naturally rich in plant food.

FULLERTON SANDY ADOBE. This name is no longer used. That mapped as such in the San Bernardino and Ventura areas has beer reclassified as Placentia sandy adobe, and that mapped under this title in the Los Angeles and Santa Ana areas has been reclassified as Placentia loam adobe.

PLACENTIA SANDY ADOBE. Mapped as Maricopa sandy adobe in the Bakersfield area, and as Fullerton sandy adobe in the San Bernardino and Ventura areas. Red to brown, three to six feet deep. SUBSOIL: Coarse, sandy adobe, shiny smooth sandy loam, decomposed granite, decayed sandstone, cemented by iron oxides and hydrates. OCCURS on level to slightly sloping land, slightly depresed, on undulating hills, not typical of any special physiographic feature. ORIGIN: From granite in place, colluvial wash from adjacent soils, degradation of limestones. CROPS: Alfalfa, grain, some fruit. Generally free from harmful accumulations of alkali.

SAN JOAQUIN SANDY ADOBE. Mapped as San Joaquin red adobe in the Fresno area. Bright red, six to ten feet. SUBSOIL: Same but heavier, hardpan. ORIGIN: From the foothill adobe. CROPS: Grain.

SIERRA SANDY ADOBE. Mapped as Sierra adobe in the Los Angeles area. Reddish brown, medium to fine texture, one to three

feet deep. SUBSOIL: Dark red, loam, gravelly loam, granite sand. OCCURS on sloping plains. ORIGIN: Composed mainly of granitic material deposited in Tertiary or earlier times. During the early Pleistocene elevation of the land, the material was raised considerably above its former level, and since then has been subjected to greater wash and weathering. The red color is doubtless due to the oxidation of the iron. CROPS: Dry farmed, citrus, deciduous fruits, berries, and truck, around Los Angeles.

GRAVELLY LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Anderson	5.4	10.5	6.4	21.9	8.1	37.5	9.9
Corning	6.8	13.0	7.9	10.1	8.8	41.4	11.9
Indio	2.4	8.5	11.8	39.4	13.4	7.1	16.5
Maricopa	11.4	13.1	8.4	19.9	14.8	19.8	9.4
Oxnard	0.9	1.6	1.3	6.9	12.5	53.8	18.9
Redding	4.9	8.3	4.8	11.0	13.2	33.9	24.2
San Joaquin	7.2	14.8	7.2	12.9	8.6	36.0	13.2
Highest	11.4	14.8	11.8	39.4	14.8	53.8	24.2
Lowest	0.9	1.6	1.3	6.9	8.1	7.1	9.4
Average	5.7	9.9	6.8	17.4	11.3	32.8	14.8

If soil contains from twenty to fifty per cent of silt and clay, they are called gravelly loams, if they contain over fifty percent of fine sand and gravel, or over twenty-five per cent of fine gravel, coarse and medium sand. These soils consist of sharp angular to water worn gravels mixed with coarse and medium sands. The texture varies from loose to compact according to the proportion of gravel present. They are loose, and porous to moderately heavy, and take water easily, but are not retentive of it. Naturally well drained, they dry quickly. They are friable when cultivated and maintain an excellent tilth. The coarse gravel gives them warmth, and they cool more slowly at night.

ANDERSON GRAVELLY LOAM. Mapped in the Redding area. Moderately heavy, light red, eight to twelve inches. SUBSOIL: Deeper red, six feet or more, stream gravels, medium hardpan. CROPS: Used mainly for grazing; adapted to peaches and grapes if well cultivated and irrigated.

ARBUCKLE GRAVELLY LOAM. Mapped in the Woodland area. Gray brown, not analyzed. SUBSOIL: Brown loam, clay loam. OCCURS: Slopes bordering streams, broad undulating areas. ORIGIN: Due to the coarser material transported by streams crossing the plains. CROPS: Raisin grapes, fruit trees, general farm crops when irrigated.

CORNING GRAVELLY LOAM. Mapped in the Red Bluff area. Light red to yellowish red, medium texture, carries gravel, boggy when wet, compact when dry; twelve to twenty inches. SUBSOIL: Red, compact heavy clay or clay loam. OCCURS on sharply rolling ground, hog-wallows. ORIGIN: Wash from Red Bluff formation. CROP: Grazing; under irrigation adapted to peaches, almonds, grapes, figs, olives.

INDIO GRAVELLY LOAM. Mapped as Imperial gravelly loam in the Imperial area. Consists of gravel composed of agate, quartz, chert, flint, limestone, granite, obsidian, and indurated clays, in size from a fraction of an inch to five or six inches, six feet or more deep. SUBSOIL: Same with more clay. OCCURS: From the old Beach Line to 125 feet below sea level. ORIGIN: Derived from granitic rocks mingled with some shale and sandstone material, and are formed by colluvial and alluvial wash from intermittent or torrential streams, wave action, torrents from mountains. CROPS: Valuable for fruits suitable for the climate, where they can be irrigated. Little alkali except in low places.

MARICOPA GRAVELLY LOAM. Mapped as Arroyo Seco sandy loam in the San Jose and Lower Salinas areas. Mapped as San Gabriel gravelly loam in the San Gabriel and Ventura areas. That mapped as Maricopa gravelly loam in the Los Angeles area has been reclassified as Maricopa fine sandy loam. Dark brown to black, locally yellowish, sharp angular gravel, five to six feet deep. SUBSOIL: Sandy gravel. OCCURS: On intermediate and upper slopes of valleys, base of abrupt slopes along the lower edges of the mountains, comparatively level or slightly rolling, rolling hills, alluvial fans. ORIGIN: Unassorted creep soil from the mountain sides, from granite schists and allied rocks. CROPS: Citrus fruits, vines, apricots, peaches, prunes, plums, almonds, olives, and other stone fruits, black-eyed beans.

OXNARD GRAVELLY LOAM. Mapped as Salinas shale loam in Ventura and Lower Salinas Valley areas. Brown to gray, simply shale ground fine, chalky material, some boulders. SUBSOIL: Oxnard loam. OCCURS: On table lands and fans, extending to the valleys as a gently sloping plain, at the mouth of deep gullies. ORIGIN: Derived from chalk-like siliceous shale, white or red, from Monterey shale mixed with other material, carried down by flood waters. CROPS: Lima beans, English walnuts, barley, wheat. Free from alkali.

REDDING GRAVELLY LOAM. Mapped in the Redding area. Red to dark red, six to fifteen inches deep, carries small cobbles. SUBSOIL: Heavy, deep, adobe-like loam, hardpan. OCCURS: Uplands, gently rolling. ORIGIN from early Pleistocene alluvium. CROPS: Depends upon the nearness of the hardpan to the surface; peaches, vines, grapes, strawberries; orchards if hardpan is dynamited. Free from alkali.

SAN JOAQUIN GRAVELLY LOAM. Mapped in the Colusa and Marysville areas, deep red to yellowish red, twelve inches to six feet deep. SUBSOIL: Deep red, heavy, dense loam or clay loam. OCCURS: On rolling plains, and slopes of lower foothills, marked by hog-wallow mounds and knolls. ORIGIN: Alluvial and lacustrine deposit, derived from the Red Bluff formation (Pleistocene). CROPS: Grazing, dry farming to grain when drained; with intense cultivation, adapted to fruits and vines.

TEHAMA GRAVELLY LOAM. Mapped in the Red Bluff area. Yellow brown to red gray. Compact to hard on drying, carries angular rock fragments, eighteen to seventy-two inches. OCCURS: On bor-

dering intermittent streams, and as terraces and benches. ORIGIN: Wash from higher lying soils, well drained. CROP: Grain; under irrigation adapted to peaches, berries, almonds, apricots, melons, alfalfa.

GRAVELLY FINE SANDY LOAM

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Elder	3.0	7.6	9.6	38.6	11.8	23.4	5.9
Mocho	2.7	7.1	6.3	24.9	28.7	23.2	7.2
Vina	1.9	3.6	4.6	17.7	24.6	21.6	25.5
Average	2.5	6.1	6.8	27.0	21.7	22.7	12.9

ELDER GRAVELLY FINE SANDY LOAM. Mapped in the Red Bluff area. Gray, very variable in texture, porous, leachy, eighteen to seventy-two inches. SUBSOIL: Sands and silts. OCCURS as alluvial stream bottoms, overflowed, limited areas. VEGETATION: Underbrush and tree growth. CROP: Pasture.

MOCHO GRAVELLY FINE SANDY LOAM. Mapped in the Livermore area. Brown, gray, gray yellow, ten to thirty-six inches. SUBSOIL: Coarse gravel. OCCURS: Base of hills, marked by abandoned stream channels. ORIGIN: Alluvial. VEGETATION: Sycamore trees. CROP: Grazing; adapted to truck and small fruit.

VINA GRAVELLY FINE SANDY LOAM. Mapped in the Red Bluff area. Brown, variable texture, twenty to thirty inches. SUBSOIL: Cobbles and volcanic materials. OCCURS on valley plains, surface strewn with angular volcanic cobbles and boulders. ORIGIN: Reworked product of the Tuscan soil. CROP: Grazing, grain.

STONY SANDY LOAM

TUSCAN STONY SANDY LOAM. Mapped in the Red Bluff area. Reddish to reddish brown; covered with boulders of volcanic material, three to twelve inches. SUBSOIL: Cemented water-worn gravel. OCCURS on land covered by recent volcanic flows. ORIGIN: Residual from lava. CROP: Non-agricultural except in small favored areas. PHYSICAL ANALYSIS: Fine gravel 7.4, coarse sand 14.7, medium sand 7.9, fine sand 11.7, very fine sand 16.9, silt 28.9, clay 12.3.

GRAVELLY SANDY LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Arbuckle	9.2	12.1	9.1	22.9	16.1	22.4	7.7
Livermore	10.1	10.5	6.7	12.0	11.7	36.8	12.2
Maywood	12.9	11.8	6.2	15.9	12.7	31.6	8.6
Pleasanton	8.5	11.5	7.2	12.9	13.8	32.1	14.1
Sacramento	11.1	20.6	11.9	19.4	11.8	18.7	6.3
San Joaquin	6.6	17.7	9.0	13.1	8.8	31.9	12.9
Sites	4.1	8.8	6.7	18.1	18.6	31.8	12.0
Highest	12.9	20.6	11.9	22.9	18.6	36.8	14.1
Lowest	4.1	8.8	6.2	12.0	8.8	18.7	6.3
Average	8.9	13.2	8.1	16.3	13.3	29.3	10.5

These soils, as the name indicates, contain large proportions of

the coarsest sands, and very little silt and clay, and are consequently light, open, porous, and not retentive of water.

ARBUCKLE GRAVELLY SANDY LOAM. Mapped in the Woodland area. Gray to yellow brown, reddish brown to pink when wet, four feet deep, boggy in wet weather. SUBSOIL: Gravelly clay loam, gravelly clay. OCCURS: As narrow ridges along old stream beds, on broad uniform slopes. ORIGIN: Alluvial. CROPS: Grape vineyards, fruits.

LIVERMORE GRAVELLY SANDY LOAM. Mapped in the Livermore area. Dark brown, contains angular fragments of a great variety of rocks, two to three feet. SUBSOIL: Same as soil, lighter in color, coarser. OCCURS on benches along creeks. ORIGIN: Colluvial and alluvial. VEGETATION: Valley oak, burr clover, alfilaria. CROP: Hay, grain.

MAYWOOD GRAVELLY SANDY LOAM. Mapped in the Red Bluff area. Gray brown, carries gravel, puddles slightly when wet, six feet. SUBSOIL: Gravel to loam. OCCURS: Bordering small intermittent streams. ORIGIN: Alluvial wash. CROP: Adapted to olives, peaches, alfalfa, etc.

PLEASANTON GRAVELLY SANDY LOAM. Mapped in the Livermore area. Brown, contains angular cobbles, eighteen to thirty inches. SUBSOIL: Reddish clay loam. OCCURS on rough hills broken by deep ravines. ORIGIN: Sedimentary. VEGETATION: Field oak, live oak, buckeye. CROP: Grazing.

REDDING GRAVELLY SANDY LOAM. Mapped in the Red Bluff area. Light red to red, sticky, carries medium to large gravel, twelve to fourteen inches. SUBSOIL: Red clay loam, underlain by red clay. OCCURS on low rolling hills. ORIGIN: A Pleistocene alluvial deposit. VEGETATION: Upland oak and manzanita. CROP: Grain, dry farming; with irrigation it is adapted to berries, peaches, alfalfa. Drainage poor.

SACRAMENTO GRAVELLY SANDY LOAM. Mapped in the Redding and Colusa areas. Light brown to reddish brown, gray, contains fragments of volcanic and metamorphic rocks. ORIGIN: From rocks of volcanic and metamorphic origin; light to slightly sticky, two to six feet deep. SUBSOIL: Cobbles, gravel. OCCURS in irregular bodies, long narrow strips, in gulches and ravines, across valley slopes, marking the course of former streams, mixed with finer sediments. CROPS: Peaches, fruit, grains.

SAN JOAQUIN GRAVELLY SANDY LOAM. Mapped in the Madera area. Dark red, two to six feet. SUBSOIL: Hardpan. OCCURS as pronounced ridges on plains. ORIGIN: Reworked lacustrine material. CROP: Grain, grapes, figs, olives, probably citrus.

SITES GRAVELLY SANDY LOAM. Mapped in the Woodland area. Yellow to red brown, heavy, well drained, fourteen to thirty inches. SUBSOIL: Brown to red gravelly loam, heavy sandy loam, weathered conglomerate or shale. OCCURS: Rolling, undulating, knolls, and low hills. ORIGIN: Coarser grades of material from wash or assorting action of water. CROPS: Grain, pasture, almonds, apricots, grapes.

CHAPTER XIX

FINE SANDY LOAMS

SANDY LOAMS. SILTY FINE SANDY LOAMS. GRAVELLY SAND. GRAVEL. COARSE SANDY LOAMS. LOAMY COARSE SAND. COARSE SAND.

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Anderson	5.4	10.5	6.4	21.9	8.1	37.5	9.9
Arbuckle	0.4	5.8	10.6	33.3	20.5	17.1	12.1
Arnold	0.5	2.4	6.7	25.8	32.0	23.5	6.6
Fresno	0.0	2.4	6.7	25.8	32.0	23.5	6.6
Gila	0.0	0.5	1.2	16.4	26.2	38.7	16.6
Hanford	0.7	3.3	3.3	18.1	27.1	35.6	9.2
Indio	0.0	0.7	1.7	19.4	34.7	25.0	17.7
Madera	0.4	1.4	3.1	23.5	42.8	18.9	9.6
Maricopa	2.8	6.3	5.2	19.7	24.9	29.5	11.9
Maywood	1.8	2.6	2.7	15.1	37.4	30.4	9.6
Media	1.7	2.5	1.7	12.3	41.6	17.6	22.5
Mocho	0.0	0.2	1.0	21.0	26.0	41.5	10.0
Orland	0.4	2.7	5.2	23.7	21.5	33.5	11.8
Oxnard	1.6	5.7	7.2	32.3	19.2	24.8	8.9
Pajaro	0.0	0.0	0.3	30.0	22.9	38.2	8.4
Placentia	4.2	8.0	7.0	19.1	19.6	28.3	12.1
Poplar	0.6	4.4	3.6	24.7	19.2	38.6	8.7
Sacramento	0.0	0.3	0.5	32.7	24.0	31.2	8.1
San Joaquin	1.0	7.8	7.7	25.3	16.3	27.2	14.4
Santiago	1.7	4.8	5.3	25.9	26.9	26.7	6.6
Stockton	1.0	3.4	11.4	22.6	24.3	22.8	10.8
Ulmar	0.4	6.0	4.8	20.7	21.0	32.9	10.0
Vina	0.5	2.6	5.7	27.1	33.8	22.1	7.8
Yolo	0.2	1.2	2.2	25.2	36.3	23.3	11.6
Highest	5.4	10.5	11.4	33.3	42.8	41.5	22.5
Lowest	0.0	0.0	0.3	12.3	8.1	17.1	6.6
Average	1.0	3.2	4.6	23.4	26.6	28.7	10.4

If soils contain from twenty to fifty per cent of silt and sand they are called fine sandy loam, if they contain over fifty per cent of fine sand, or less than twenty-five per cent of fine gravel, coarse and medium sand.

They are the most important soils of the state on account of the variety, yield and value of intensively cultivated crops, and are adapted to any crop suited to the local and climatic conditions. They are smooth, loose, porous, light and friable, and generally well drained on account of their texture giving ready percolation. They possess strong capillary power and are moderately rentention of moisture under cultivation, but are sometimes sticky when too wet, packing some and having a tendency to puddle. At first they were used only for grazing and dry farming; later, alfalfa, barley, wheat, potatoes, etc., were planted

extensively; but they are now noted for their special crops, under irrigation and intensive cultivation, of citrus, olives, walnuts, peaches, pears, wine and raisin grapes, hops, asparagus, sugar beets, melons, strawberries, peanuts, etc., etc.

ANDERSON FINE SANDY LOAM. Mapped in the Redding area. Light red to reddish gray, three to six feet. SUBSOIL: River sands, hardpan, clays, volcanic tuff. CROPS: Adapted to peaches, pears, grapes, small fruits, dry farming, grain.

ARBUCKLE FINE SANDY LOAM. Mapped in the Woodland area. Brown, six feet. SUBSOIL: Sandy or silty loam, gravel, yellowish brown. OCCURS: Level, well drained. ORIGIN: Alluvial. CROPS: Fruit and garden.

ARNOLD FINE SANDY LOAM. Mapped in the Modesto-Turlock area. Chocolate brown, micaceous, contains some gravel, three to five feet deep. SUBSOIL: Similar to the soil but heavier. OCCURS on the crest of hills, above river terraces. ORIGIN: Alluvial, lacustrine. CROPS: Grain, adapted to fruit, vegetables, grapes.

FRESNO FINE SANDY LOAM. Mapped in the Indio, Modesto-Turlock, Madera, and Stockton areas. Mapped as Fresno sandy loam in the Fresno area. That mapped as Fresno fine sandy loam in the Bakersfield, Los Angeles, Lower Salinas Valley, San Bernardino, and San Gabriel areas has been reclassified as Hanford fine sandy loam. That mapped as Fresno fine sandy loam in the Ventura area has been reclassified as Oxnard loam. That mapped as Fresno fine sandy loam in the San Jose area has been reclassified as Hanford silt loam. Light gray, ashy, fifteen inches to five feet deep. Called "White Ash Land" around Fresno. SUBSOIL: White to bluish hardpan. OCCURS: In irregular, elongated areas, surface low, flat, or slightly depressed. ORIGIN: Derived from white sands, volcanic ash, and granitic material. CROPS: Mainly given to grazing, where well drained grains, vines and small fruits do well; alfalfa, vines, figs, peaches, berries, melons; valuable fruit land around Selma. The alkali in the subsoil makes it sometimes difficult to reclaim the land where the drainage is poor.

GILA FINE SANDY LOAM. Mapped in the Imperial area. Mapped as Imperial sandy loam in the Yuma-California area. Reddish brown, three to six feet deep. SUBSOIL: Light loam or sandy loam which in turn is underlain by loam, clay loam, clay or sand. OCCURS: Level, or slightly scored by the wind. ORIGIN: Direct deposit from rivers; and sand blown or washed in from the mesas. CROPS: Adapted to all the field and fruit crops suitable for the climate. One of the best soils in Imperial Valley. Generally free from alkali.

HANFORD FINE SANDY LOAM. Mapped in the Hanford, Madera and Woodland areas. Mapped as Fresno fine sandy loam in the Bakersfield, Sacramento, Santa Ana, Salinas Valley, San Bernardino, and San Gabriel areas. Light to dark gray or drab, brown, buff, yellowish reddish, six feet deep. SUBSOIL: Very variable, often sand. OCCURS: In local depressions, near slouughs or drainage basins, on the lower terraces and river bottoms subject to overflow, on level delta

plains, adjacent to river and slough channels and tidal flats. ORIGIN: From the fine micaceous material derived from granitic, diabasic and other fine textured rocks of the foothills and mountains deposited over the flood plains from the slack waters of the streams. CROPS: Among the most important on account of the variety, value, and yield; adapted to any crops suited to the local climatic conditions; walnuts, citrus, apples, pears, celery, sugar beets, raisin grapes, hops, asparagus, alfalfa, grain, potatoes, truck. There is rarely enough alkali to exclude useful crops.

INDIO FINE SANDY LOAM. Mapped as Fresno fine sandy loam in the Indio area. Slate colored, two to five feet. SUBSOIL: Sandy loam, sand. OCCURS: Uniform slopes, from 250 feet below sea level to 100 above. ORIGIN: Same as Indio fine sand. CROPS: The best for general purposes; melons, sweet potatoes, garden crops, etc. Some alkali in spots.

LIVERMORE FINE SANDY LOAM. Mapped in the Livermore area. Brown, variable texture, two feet. SUBSOIL: Yellow sandy loam. OCCURS in ridges marking the course of former streams. Well drained. ORIGIN: Colluvial and alluvial. CROP: Dry farmed to grain and hay. Adapted to small fruit, truck, alfalfa.

MADERA FINE SANDY LOAM. Mapped in the Madera area. Brown, fifty to sixty inches. OCCURS on lowlands bordering streams. ORIGIN: Alluvial. CROP: Grain; adapted to alfalfa, grapes, small fruit.

MARICOPA FINE SANDY LOAM. Mapped as Maricopa gravelly loam in the Los Angeles area. Dark brown to brown, gravel, pebbles and cobbles, three to six feet. SUBSOIL: Waterworn granitic sand, gravel and boulders. OCCURS: Level terraces along streams, sloping plains. ORIGIN: Granitic material brought from the mountains by river and streams. CROPS: Grapes, strawberries, oranges, peaches, apricots, alfalfa, etc. Free from alkali.

MAYWOOD FINE SANDY LOAM. Mapped in the Red Bluff area. Yellowish gray, friable, does not puddle or crack, twenty-four to thirty inches. SUBSOIL: Loam or gravelly loam. OCCURS: Bordering streams, level, well drained. ORIGIN: Wash from higher soils. CROP: Alfalfa, peaches, prunes, apricots, melons, truck.

MEDIA FINE SANDY LOAM. Mapped in the Madera district. Red, two to six feet. SUBSOIL: Clay loam. OCCURS on rolling land. ORIGIN: Residual. CROPS: Grain; locally to grapes, figs, olives, alfalfa.

MOCHO FINE SANDY LOAM. Mapped in the Livermore area. Brown to gray brown; eighteen to twenty-four inches. OCCURS along stream channels. ORIGIN: Alluvial from overflow of creeks in flood. CROP: Sugar beets, truck.

ORLAND FINE SANDY LOAM. Mapped in the Colusa area. Reddish to reddish gray, few inches to three feet deep. SUBSOIL: Underlain by partially weathered sandstone. OCCURS: On elevated foothill ridges, steep slopes, unirrigable. ORIGIN: Residual, derived from sandstone in place. CROPS: Dry farming; grain, grazing, adapted to

fruits, vegetables, and sugar beets under irrigation. Free from alkali.

OXNARD FINE SANDY LOAM. Mapped in the San Bernardino area. Greenish gray, micaceous, some gravel, one to two feet deep. SUBSOIL: Heavy, sticky, gray sandy loam, or loam. OCCURS: Smooth, level. ORIGIN: Wash from incoherent sandstones which weather into fantastic shapes locally called "Bad Lands." CROPS: Wheat, alfalfa. Alkali where poorly drained.

PAJARO FINE SANDY LOAM. Mapped in the Pajaro area. Brown, micaceous, eighteen to seventy-two inches. SUBSOIL: Black loam, or silt loam. OCCURS along the rivers and creeks. ORIGIN: Alluvial and sedimentary. CROPS: Apples, alfalfa, tomatoes, beans, sugar beets, cantaloupes, cucumbers, strawberries, loganberries, blackberries.

PLACENTIA FINE SANDY LOAM. Mapped as Placentia sandy loam in the Los Angeles, Lower Salinas Valley, San Bernardino, San Jose, San Gabriel and Santa Ana areas. Reddish brown, brown, reddish yellow, eighteen inches to six feet deep. The Gravelly Phase contains a high percent of gravel. SUBSOIL: Hardpan, compact loam, sandy adobe. OCCURS in large bodies on hills, level to steep, low rolling hills, mesas, mountain slopes, coastal plains. ORIGIN: The origin of this soil is similar to that of many others and may be used as an illustration of the origin of sandy loams in general. The greater part has been found in place, but some is due to soil-creep from the base of the hills. In the Lower Salinas Valley, bordering the Gavilan Range, and Sierra Salinas, it is derived from Jurassic and older rocks consisting chiefly of fragments of gneiss, schists and granites, brought down and distributed by torrential streams from canyon mouths. In the Los Angeles area it is the weathered product of granitic material that was transported, as above, in late Tertiary times. These old washings of Pleistocene times were elevated by a movement of the earth's crust, and have since then been much modified by weathering. They have also been wind blown along the coast. In the San Jose area the fine material has been carried a long distance along the slope of the mountains and the alluvial fans, or cones, extending outward from canyon mouths. These cones often merge and form broad gently sloping mesa lands. Where the sandy loam is the result of the breaking down of sandstone or conglomerate the soil contains gravel and assumes a gravelly phase as in the San Gabriel area where the soil north of Puente is formed partially from the wash of Walnut Creek, which drains a sandstone and shale area, and partially from the wash of San Dimas Canyon, which drains a granitic area. CROPS: Citrus fruits at Riverside, Redlands, Whittier, La Mirada, Santa Fe Springs, Montebello, Pico Heights, Palms, Inglewood, Gardena, San Dimas, and in Orange County, walnuts at Whittier, olives, grapes, truck, berries, alfalfa, grain, prunes, peaches, wine grapes, cherries, etc. Generally free from alkali.

POPLAR FINE SANDY LOAM. Mapped in the Portersville area. Light brown to buff, micaceous, two to four feet deep. SUBSOIL: Reddish or yellowish brown clay loam. OCCURS: In small irregular patches, level. ORIGIN: Alluvial, the subsoil is reworked Pleistocene material mixed with recent material. CROPS: Pasturage, dairying,

alfalfa, small fruits, deciduous fruits, truck gardens. Practically free from alkali.

SACRAMENTO FINE SANDY LOAM. Mapped in the Colusa, Woodland, Redding, Red Bluff, and Sacramento areas. Light gray to dark brown, micaceous, eighteen inches to six feet. SUBSOIL: Gravels, sandy loams. OCCURS in irregular, narrow, elongated bodies, near stream channels, sloughs, uneven, sloping. ORIGIN: Recent alluvial. CROPS: Alfalfa, peaches, prunes, pears, plums; melons, hops, potatoes, corn, English walnuts, wheat, barley.

SAN JOAQUIN FINE SANDY LOAM. Mapped in the Colusa, Marysville and Sacramento areas. Light red to buff, ten inches to three feet. SUBSOIL: Red loam, light brown clay loam, heavy indurated clay. OCCURS: In irregular shaped bodies, on undulating and smooth valley plains, upper benches of ancient flood plain. ORIGIN: Lacustrine, from Red Bluff formation. CROPS: Grazing, grain; with irrigation adapted to grapes, citrus fruits, stone fruits, berries, Tokay grapes, strawberries.

SANTIAGO FINE SANDY LOAM. Mapped as Santiago sandy loam in the Santa Ana area, three to four feet deep. SUBSOIL: Sand twelve to thirty feet, sand adobe. OCCURS on the higher elevations, uplands, broken country. CROPS: Truck, peanuts, wheat, barley, small fruits, oranges and walnuts at Orange and Tustin.

STOCKTON FINE SANDY LOAM. Mapped as Fancher sandy loam in the Fresno area. Red, micaceous, high percent of organic matter, six feet deep. SUBSOIL: Same, gravelly. OCCURS along foothill streams, around sinks, in low lying tracts. ORIGIN: Result of stream deposits. CROPS: Typical raisin soil. Minor spots of alkali.

ULMAR FINE SANDY LOAM. Mapped in the Livermore area. Brown, thirty to seventy-two inches. SUBSOIL: Yellow fine sandy loam with hardpan at from three to five feet. OCCURS on valley floor, marked by old stream channels and some hogwallows. ORIGIN: Colluvial and alluvial. VEGETATION: Greasewood, alkali heath, salt grass. Some alkali. CROPS: Grazing, hay, grain.

VINA FINE SANDY LOAM. Mapped in the Red Bluff area. Dark grey to gray brown, micaceous, uniform texture, six feet. SUBSOIL: Gravel. OCCURS on sloping valley plains, bordering streams, marked by old channels, poorly drained. ORIGIN: Alluvial, recent deposit of streams. VEGETATION: Oak, willow, grapevines. CROPS: Alfalfa, peaches, wine grapes, truck, melons, stone fruits.

YOLO FINE SANDY LOAM. Mapped in the Woodland area. Light brown, contains streaks of sand and thin beds of silt, surface sometimes contains wind-blown sand, fifteen inches. SUBSOIL: Brown sand, sandy loam, loam, silt loam. OCCURS as numerous small bodies, sloping or slightly undulating, between creeks, lower bench lands. ORIGIN: Recent from the shifting currents of the larger creeks during flood periods. CROPS: Alfalfa, vines, grain, peaches, apricots, almonds, grapes, prunes, truck gardens, sugar beets, general farm crops.

SANDY LOAMS

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Arnold	10.2	29.4	10.3	12.4	3.5	24.6	9.6
Bellavista	0.0	6.6	20.1	44.6	4.8	15.0	7.9
Contra Costa	3.8	19.1	16.3	20.3	8.8	22.7	8.9
Encina	2.1	13.9	19.7	26.5	13.7	16.7	7.5
Exeter	4.3	17.1	7.8	17.5	7.3	31.7	14.5
Fresno	1.1	7.4	6.7	21.0	16.2	35.9	9.9
Gridley	5.0	20.5	14.2	26.1	8.0	16.0	10.2
Hanford	7.6	25.1	12.9	34.5	7.1	10.2	3.0
Imperial	0.0	0.2	0.4	9.3	20.3	47.6	15.4
Madera	1.7	22.0	18.5	21.1	9.6	19.1	7.9
Maricopa	10.1	19.0	11.5	21.0	12.4	17.1	8.8
Media	6.4	12.9	7.3	24.5	25.2	16.5	7.2
Monterey	0.1	7.0	22.4	35.3	1.7	23.1	10.3
Oakdale	5.2	22.1	10.1	21.8	9.1	24.6	7.6
Oxnard	0.3	2.2	3.4	19.1	26.4	34.2	10.3
Pajaro	0.1	7.0	16.6	37.1	4.9	24.4	9.3
Placentia	10.6	13.2	6.7	19.1	20.6	18.9	10.7
Pleasanton	3.4	9.1	6.9	18.1	20.8	30.6	11.2
Sacramento	0.7	14.2	10.1	40.4	11.5	14.6	8.4
San Joaquin	4.0	10.5	10.6	18.2	20.2	23.6	10.9
Santa Cruz	0.3	17.4	22.5	36.0	3.4	10.0	10.3
Sheridan	2.5	10.9	8.0	31.0	18.7	16.8	11.2
Sierra	13.0	23.6	10.0	17.6	7.4	15.0	12.8
Sites	0.0	6.0	9.4	26.6	11.0	27.6	19.4
Sutter	4.6	11.5	6.8	24.3	14.4	24.3	14.1
Watsonville	0.1	3.1	4.5	17.5	7.2	55.8	11.3
Highest	13.0	29.4	22.5	44.6	26.4	55.8	19.4
Lowest	0.0	0.2	0.4	9.3	1.7	10.0	3.0
Average	3.7	16.1	12.9	24.7	12.5	23.7	10.2

When soils contain from twenty to fifty per cent of silt and clay they are called sandy loam. If they contain over twenty-five per cent of fine gravel, coarse and medium sand, they are light and mellow and usually of fine texture, but may vary widely in this respect. They are often hard and compact when dry, compact and sticky or plastic, with a tendency to pack when wet, but loose and friable under cultivation. They take water well but become heavier under irrigation, being easily cultivated when handled at the right time; but when too moist break up into clods. The drainage depends upon local conditions, and they are apt to wash under heavy rains. With thorough artificial drainage and plenty of irrigating waters they make a fine soil for fruit and general farming, forming a moisture-retaining mulch when cultivated. Only depressed areas incapable of drainage and irrigation are of no agricultural importance.

ARNOLD SANDY LOAM. Mapped in the Modesto-Turlock area. Gray to brown, contains coarse granite and quartz sand and pebbles. SUBSOIL: Yellowish red, clay, coarse sand and silt. OCCURS: Any place in the foothills. ORIGIN: Lacustrine and alluvial. CROPS: Dry farming, adapted to grapes, olives, almonds, and figs if properly managed.

BELLAVISTA SANDY LOAM. Mapped in the Redding area. Light ash-gray, well drained, one to six feet. SUBSOIL: Adobe-like sandy clay, a clay hardpan, volcanic ash and tuff. OCCURS: Occupies gently sloping valley plains or lower rolling hill slopes. ORIGIN: From the

erosion of adjacent beds of volcanic ash and tuff and the distribution of this material with the gravels and soils derived from the uplands. CROPS: Of limited acreage and minor agricultural importance.

CONTRA COSTA SANDY LOAM. Mapped in the Livermore area. Brown when wet, yellowish when dry, twelve to sixty inches. SUBSOIL: Bedrock. OCCURS on low broken hills. ORIGIN: Residual from coarse grained sandstone and conglomerate. VEGETATION: Live oak, field oak. CROP: Grain, hay, adapted to eucalyptus.

DAULTON SANDY LOAM. Mapped in the Madera area. Grayish to dark brown, five to forty-eight inches. SUBSOIL: Metamorphic rocks or granite. OCCURS on eroded steep rolling lands or foothills. ORIGIN: Residual. CROPS: Grazing.

ENCINA SANDY LOAM. Mapped in the Pajaro area. Drab gray to dark brown, coarse, sharp fragments of granite, quartz and shale, two feet. SUBSOIL: Gray heavy sandy loam, sandy adobe. OCCURS: Slopes of the foothills. ORIGIN: Residual. CROPS: Grapes, apples, apricots.

EXETER SANDY LOAM. Mapped in the Portersville area. Dark to reddish brown, fine gravel, drainage good, six feet. SUBSOIL: Similar but more compact. OCCURS: Level. ORIGIN: Wash from the adjacent soils, recent alluvial. CROPS: Grain, citrus fruits, grapes, peaches. Free from alkali.

FRESNO SANDY LOAM. Mapped in the Hanford and Modesto-Turlock areas. That mapped as Fresno sandy loam in the Fresno area is Fresno fine sandy loam. That in the Indio area is Indio fine sand, called "White Ash Land" in many parts of the San Joaquin Valley. White to gray, fine ash, two to three feet. SUBSOIL: Lime-magnesium hardpan, contains salt and alkali. OCCURS: In irregular-shaped bodies. ORIGIN: Derived from white sands, volcanic ash, and granitic material. CROPS: With thorough artificial drainage and plenty of irrigating water makes a fine soil for fruit and general farming; grain, alfalfa, figs, peaches, olives, berries, vines, melons, vegetables, etc. Alkali in depressed areas.

GRIDLEY SANDY LOAM. Mapped in the Marysville area. Reddish brown, contains waterworn gravel, thirty inches to six feet, drainage good. SUBSOIL: Dark brown sticky loam. OCCURS: Level to slightly rolling. ORIGIN: Sedimentary, reworked by later alluvial agencies. CROPS: Pasture, grain, peaches, grapes, alfalfa, berries.

HANFORD SANDY LOAM. Mapped in the Madera and Portersville area. Mapped as Fancher sandy loam in the Hanford area, gray to buff, six feet. SUBSOIL: Yellow or sticky loam. OCCURS in elongated irregular bodies, level or uniform surface, along streams, delta plains, coastal plains, lower terraces, valley floors. ORIGIN: Alluvial, granitic material from the mountains reworked and deposited by streams during floods. CROPS: Alfalfa, grain, deciduous fruits, grapes, general utility soil. Traces of alkali.

IMPERIAL SANDY LOAM. Mapped in the Imperial area. Coarse river sediment, three feet. SUBSOIL: Heavy sandy loam, loam. OCCURS in large bodies, irregular in form. ORIGIN: Colorado

River deposits, mixed with wind-blown sand. CROPS: Best for intertillage crops, fruits, dates, sugar beets, vegetable and general utility. Wide range of alkali conditions; some areas free, others badly affected.

MADERA SANDY LOAM. Mapped in the Madera area. Brown, one to six feet. SUBSOIL: Red hardpan. OCCURS on rolling or dissected plains, marked by hogwallows. ORIGIN: Reworking of older residual soils. CROP: Grain, grazing, local adapted to figs, olives, berries, alfalfa.

MARICOPA SANDY LOAM. Mapped in the Los Angeles area. Mapped as San Gabriel sandy loam in the San Bernardino area. Light gray to yellowish, brown to reddish, three to six feet. OCCURS on hill and mountain slope. ORIGIN: Residual, colluvial, detritus from granite and closely allied rocks. CROPS: Citrus and deciduous fruits, peas, beans, tomatoes, egg plant, squashes, potatoes, peppers, pineapples at Hollywood.

MEDIA SANDY LOAM. Mapped in the Madera area. Red to gray red micaceous, carries angular fragments of feldspar, thirty to sixty inches. SUBSOIL: Granitic rocks. OCCURS on rolling land cut by intermittent stream courses. ORIGIN: Residual. CROP: Grain, grazing; local adapted to grapes, figs, olives, alfalfa; possibly to citrus.

MOCHO SANDY LOAM. Mapped in the Livermore area. Brown to gray, frequently consists of alternating strata of silty fine sand, fine and coarse sand; three to six feet. SUBSOIL: Brown to black clay, clay loam. OCCURS in long narrow strips along stream channels. ORIGIN: Alluvial by overflow of creeks. VEGETATION: Sycamore, oak, willow. CROPS: Peas, potatoes, cabbages, truck.

MONTEREY SANDY LOAM. Mapped in Pajaro area. Brown, darkened by humus, thirty inches. OCCURS: Broken, hilly, exposed slopes, ridges of the foothills of the Coast Range. ORIGIN: From the underlying shaly sandstones, and wash from higher ground. CROPS: Apricots, orchards where well cultivated.

OAKDALE SANDY LOAM. Mapped in the Modesto-Turlock area. Chocolate brown, micaceous, contains coarse sharp sand, five to six feet. SUBSOIL: White hardpan. OCCURS: Smooth, level. ORIGIN: Mingling of the material from adjacent soils. CROPS: Fine for fruit and general farming; figs, peaches, olives, berries, melons, vegetables, etc.

OXNARD SANDY LOAM. Mapped in the San Bernardino and Ventura areas. Dark brown to black, light, high in organic matter, drainage poor in places, four to five feet. GRAVELLY PHASE: Contains shale gravel. SUBSOIL: Heavy sandy loam, loam, unconsolidated sandstones. OCCURS: Level, slightly undulating, gently sloping plains, deltas, capping unconsolidated sandstones. ORIGIN: Wash from shale and sandstones. CROPS: Sugar beets, grain, truck crops, lima beans. May contain small amounts of alkali, rarely 0.20 per cent.

PAJARO SANDY LOAM. Mapped in the Pajaro area. Dark brown, easily tilled, six feet. SUBSOIL: Lighter in color and texture. CROPS: Excellent orchard soil, apples, cherries, prunes, plums, pears, walnuts, strawberries, raspberries, loganberries, blackberries, when irrigated.

PLACENTIA SANDY LOAM. Mapped in the Bakersfield area. Mapped as Placentia loam in the Ventura area. Mapped as Placentia coarse sandy loam in the San Bernardino area. That mapped as Placentia sandy loam in the San Bernardino, Los Angeles, San Jose, San Gabriel, Santa Ana, and Lower Salinas Valley area has been reclassified as Placentia fine sandy loam. Coarse, compact, well drained, three to four feet. SUBSOIL: Red, heavy, coarse and hard sandy loam. OCCURS: On the gentle slopes from the foothills. ORIGIN: Colluvial, from waste of the foothills. CROPS: Alfalfa, local small orchards. Usually free from harmful accumulations of alkali.

PLEASANTON SANDY LOAM. Mapped in the Livermore area. Reddish brown, sticky; forms a surface crust after rains. OCCURS at base of eastern slope of the Coast Range; level to rolling, limited. ORIGIN: Sedimentary. CROP: Dry farmed to hay, grain, grapes.

SACRAMENTO SANDY LOAM. Mapped in the Modesto-Turlock area. Brown, gray, micaceous, six feet. SUBSOIL: Coarse sand or gravel. OCCURS: Comparatively level, along rivers. ORIGIN: Deposited during recent overflows. CROPS: Orchards, gardens, truck gardening, berries, melons.

SAN JOAQUIN SANDY LOAM. Mapped in the Stockton, Sacramento, Marysville, Madera, Fresno, Modesto-Turlock, and Portersville areas. Light red, silty, drainage variable, eighteen inches to six feet. SUBSOIL: Fine dense hardpan, red, yellow, heavy compact gray sandy adobe; sandstone, hardpan. OCCURS: On gentle slopes, flood plains, valley floors, on hogwallow land. ORIGIN: Pleistocene lake deposits modified by alluvial wash, from adjacent granitic, volcanic and metamorphic rocks washed into the Pleistocene lake or bay. CROPS: Vary widely locally; hay, oats, barley, rye, peaches, cherries, plums, citrus fruits, Zinfandel, Tokay, Emperor, and seedless grapes. Alkali not present in injurious quuantities.

SAN JOAQUIN SANDY LOAM. Mapped in the Madera area. Red to yellow brown, eighteen to seventytwo inches. SUBSOIL: Red ferruginous hardpan. OCCURS on plains marked by hogwallows, poorly drained. ORIGIN: Lacustrine. CROP: Grain, figs, olives, grapes.

SANTA CRUZ SANDY LOAM. Mapped in the Pajaro area. Dark red, red brown, two to three feet, high iron contents. SUBSOIL: Heavy reddish sandy loam. OCCURS: Steep hillsides. ORIGIN: From sandstones in place. CROPS: Apples, wine grapes. The "redwood soils" produce the best orchards.

SHERIDAN SANDY LOAM. Mapped in the Sacramento area. Black, micaceous, drainage variable, six inches to six feet. SUBSOIL: Granitic, stream gravels. OCCURS: Lower valley slopes of the foothills. ORIGIN: Residual or colluvial from the weathering of dark colored, fine textured gabbrodiorite and grannodiorite. CROPS: When well drained adapted to grains, hay, forage crops, fruit.

SIERRA SANDY LOAM. Mapped in the Sacramento area. Light gray to red, coarse, well drained, three to six feet. OCCURS: Covers the rolling, dome-like slopes of the lower foothills, rock outcrops. ORIGIN: Disintegration in place of grannodiorite rock. CROPS:

Berries, vines, citrus fruits, deciduous fruits, peaches, plums, cherries, apricots, pears, strawberries, etc., according to local climate. No injurious amount of alkali.

SITES SANDY LOAM. Mapped in the Colusa area. Light red to reddish gray, well drained, three to six feet. SUBSOIL: Sandstone. OCCURS: Elevated foothill ridges, broken, outcrops of sandstones. ORIGIN: Residual from sandstone in place. CROPS: Grain, grazing. Free from alkali.

SUTTER SANDY LOAM. Mapped in the Marysville area. Brown, rarely black, three inches to six feet. SUBSOIL: Yellow, brown, sticky. OCCURS: In irregular areas, around the edges of buttes, in small valleys and coves; occasionally overflowed by backwaters. ORIGIN: Largely colluvial, altered by flood material, weathered andesitic rocks, tuffs, breccias. CROPS: Grain, alfalfa, almonds, peaches, berries, melons. Free from alkali.

WATSONVILLE SANDY LOAM. Mapped in the Pajaro area. Reddish brown, sharp angular sand, thirty inches to six feet, high in iron salts, drainage good. SUBSOIL: Dark red, heavy sandy loam, sandy shales, heavy silty clay loams. OCCURS: Uplands, lower portions of Coast Range. ORIGIN: Residual, from underlying shales and conglomerates. CROPS: Grain, apples, apricots, grapes, eucalyptus.

SILTY FINE SANDY LOAM

LIVERMORE SILTY FINE SANDY LOAM. Mapped in the Livermore area. Brown, thirty-six inches. SUBSOIL: Yellowish sandy loam. OCCURS on level to slightly rolling land with ridges, and former stream channels. ORIGIN: Colluvial and alluvial. CROPS: Orchard fruits, truck farms, alfalfa. PHYSICAL ANALYSIS: Fine gravel 0.0, coarse sand 0.2, medium sand 0.5, fine sand 14.6, very fine sand 32.8, silt 41.9, clay 9.9.

GRAVELLY SAND

MARICOPA GRAVELLY SAND. Mapped as San Gabriel gravelly sand in the San Gabriel area, as Soledad gravelly sand in the Salinas area, and as San Gabriel gravelly sand in the San Bernardino area. Light to dark gray, yellowish to brown, from fine sand to pieces two and three inches in diameter; the fine gravel predominates over all the other units; six feet. SUBSOIL: Same as soil, only more compact. OCCURS on steep slopes, at foot of mountains. ORIGIN: Granitic wash, direct from the mountains. CROPS: Citrus fruits, grapes, peaches, apricots. Free from excess of alkali.

GRAVEL

HANFORD GRAVEL. Mapped as Fresno gravel in the Sacramento area. The true gravel soil is composed of all grades of gravel and cobbles, with some small boulders, underlain by the prevailing rock of the locality. OCCURS along the lower river benches, on sloping hillsides, and in ravines. ORIGIN: Derived from the rocks of the mountains and foothills, spread by streams during the flood season. CROPS: On account of the impossibility of cultivation, adapted only to grazing.

COARSE SANDY LOAMS

The coarse sandy loams as the name implies, carry large amounts of gravel, medium, coarse and fine sands. This gives free movement of air and moisture, makes them warm, and light to cultivate. They are well drained, loose and incoherent when dry, but slightly sticky when wet.

HANFORD COARSE SANDY LOAM. Mapped in the Madera area. Buff, micaceous, six feet. SUBSOIL: Gravel. Occurs on low [illegible] along the San Joaquin River. ORIGIN: From river sediment CROPS: Grain, alfalfa, peaches, grapes, truck.

MEDIA COARSE SANDY LOAM. Mapped in the Madera area. Dark gray, six to forty-eight inches. SUBSOIL: Granitic rocks. OCCURS on sharply rounded hills. ORIGIN: Residual. CROPS: Grazing, grain.

OAKDALE COARSE SANDY LOAM. Mapped in the Modesto-Turlock area. Chocolate, reddish or yellowish brown, micaceous, twelve inches. SUBSOIL: Yellow gray sand loam, free from hard-pan. OCCURS: Level land, along rivers. ORIGIN: Alluvial, modified by old channel material. CROPS: Strawberries, bramble berries, almonds, olives, citrus, melons, vegetables. Free from alkali. Physical analysis: Fine gravel 13.2, coarse sand 38.8, medium sand 11.1, fine sand 14.0, very fine sand 2.7, silt 14.4, clay 5.2.

PORTERSVILLE COARSE SANDY LOAM. Mapped in the Portersville area. Black, micaceous, one to six feet. SUBSOIL: Granitic rocks. OCCURS on lower slopes of the foothills. ORIGIN: Residual from the underlying granite, more or less modified by alluvial wash. CROPS: Grain; adapted to citrus and deciduous fruits under irrigation. PHYSICAL ANALYSIS: Fine gravel 6.4, coarse sand 20.0, medium sand 10.3, fine sand 21.5, very fine sand 9.4, silt 22.3, clay 9.9.

LOAMY COARSE SAND

In these soils the very fine sand predominates giving the soil a loamy character.

FRESNO LOAMY COARSE SAND. Mapped in the Madera area. Brown to gray, one to six feet. SUBSOIL: Bluish hardpan. OCCURS on lower plains, and in swampy ground. ORIGIN: From former and present sloughs, modified by surface erosion. Drainage poor. CROPS: Alfalfa, grapes, adapted to peaches, figs, olives, and small fruit where it can be drained. PHYSICAL ANALYSIS: Fine gravel 8.1, coarse sand 22.3, medium sand 12.7, fine sand 21.7, very fine sand 25.8, silt 5.6, clay 3.8.

COARSE SAND

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Fresno	12.0	29.7	18.4	23.6	8.8	4.3	3.1
Hanford	10.0	28.7	16.4	19.6	8.2	12.2	4.8
Madera	10.7	25.6	15.3	21.1	12.8	6.9	7.6
Average	10.9	28.0	16.7	21.4	6.6	7.8	5.1

FRESNO COARSE SAND. Mapped in the Madera area. Gray to yellow gray, six feet. SUBSOIL: Brown sand. OCCURS on valley plain, marked by old water courses. ORIGIN: Alluvial. CROPS: Adapted to peaches, vines, alfalfa.

HANFORD COARSE SAND. Mapped in the Madera area. Brown to gray brown, micaceous, six feet. SUBSOIL: Same or finer material. OCCURS: Along old river channels. ORIGIN: Alluvial, from flood of present streams. CROPS: Adapted to alfalfa.

MADERA COARSE SAND. Mapped in the Madera area. Brown, micaceous, four to six feet. SUBSOIL: Red hardpan. OCCURS: As narrow bodies following the meandering of streams, as knolls and ridges between streams. ORIGIN: Reworking of the original hardpan. CROP: Grain.

CHAPTER XX

FINE SANDS

RIVER WASH AND ROCK OUTCROP. ROUGH STONY LAND. PEAT. MUCK. LAKE AND MARSH. MEADOW SAND. DUNE SAND.

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Fresno	1.5	8.5	8.2	37.3	22.0	17.6	5.5
Hanford	0.0	1.2	4.8	33.3	32.1	21.3	3.8
Indio	0.1	0.5	2.8	27.7	51.3	13.7	3.1
Sacramento	0.1	1.0	2.9	59.1	20.6	14.0	2.9
Highest	1.5	8.5	8.2	59.1	51.3	21.3	5.5
Lowest	0.0	0.5	2.8	27.7	20.6	13.7	2.9
Average	0.4	2.8	4.7	39.3	31.5	16.4	3.8

Soils that contain less than twenty per cent of silt and clay are called fine sand, if they contain more than fifty per cent of fine sands, or less than twenty-five per cent of fine gravel, coarse and medium sand. These soils are generally micaceous, light, smooth, open, porous, friable, incoherent and well drained, unless the water table is locally high. They are not retentive of moisture, and are easily cultivated.

FRESNO FINE SAND. Mapped in the Modesto-Turlock and Stockton areas. That mapped as Fresno fine sand in the Los Angeles and Bakersfield areas has been reclassified as Hanford fine sand. That mapped as Fresno fine sand in the Indio area has been reclassified as Indio fine sandy loam. That classified as Fresno fine sand in the Sacramento area has been reclassified as Hanford fine sandy loam. Light yellow, light brown, gray brown, three to six feet. SUBSOIL: Similar, heavier, tenacious when wet. OCCURS: In long narrow areas, generally level. ORIGIN: Micaceous granitic material predominates. CROPS: When irrigated, adapted to alfalfa, forage, hard fruits, vines, etc., requiring a loose, well drained soil. The alkali in the subsoil is not injurious when the land is well drained.

HANFORD FINE SAND. Mapped in the Hanford, Lower Salinas Valley and Madera areas. Mapped as Fresno fine sand in the Bakersfield and Los Angeles areas. Yellowish, well drained, three to six feet. SUBSOIL: Fine sand, loam, sandy loam. OCCURS: On delta plains, slightly elevated ridges, lower valley floors, river terraces, along former stream channels, level, in irregular shaped bodies. ORIGIN: Sedimentary deposits, originally derived from the disintegration of granitic rocks, deposited by local streams, carried by currents of moderate velocity and deposited in slack waters. CROPS: Truck, alfalfa, fruit. Some alkali in the surface foot where the land has not been cultivated or irrigated.

INDIO FINE SAND. Mapped as Fresno sandy loam in the Indio area. Grayish, poorly drained, high water table, three to six feet. SUBSOIL: Coarse sand. OCCURS: On the slopes below the Indio sand, full of blowouts, small dunes, and shallow depressions. ORIGIN: Derived from the wash from the mountains and deposited under the waters of the basin when it was an arm of the sea. CROPS: Where it is not too alkaline will produce any crops adapted to the climate.

ORLAND FINE SAND. Mapped in the Colusa area. Dark drab, six inches to three feet. SUBSOIL: River sands and gravel. OCCURS: In small bodies in bottom lands, a little above stream channels. ORIGIN: Recent stream deposits. CROPS: Dry farming, grain, hay, pasture. Generally free from alkali. Not analyzed.

SACRAMENTO FINE SAND. Mapped in the Marysville and Woodland areas. Brown, yellow, buff, variable in texture, six to eighteen inches. SUBSOIL: Silty, loamy or coarser sand material. OCCURS: On higher elevations approaching the river. ORIGIN: Alluvial. CROPS: Garden truck, small fruits.

SAND

	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Fresno	2.1	16.8	22.0	25.8	18.7	11.1	3.0
Hanford	5.1	14.6	15.5	32.5	16.6	7.9	3.7
Imperial	0.0	18.0	21.9	34.1	24.1	0.2	1.7
Madera	1.5	21.4	25.7	27.6	9.5	9.4	4.2
Maricopa	2.4	13.5	26.6	33.9	15.8	4.9	2.8
Oakdale	0.0	11.3	25.8	45.5	5.3	8.9	2.2
Oxnard	0.7	8.6	22.5	32.4	16.2	11.3	6.2
Sacramento	0.0	3.1	30.5	60.0	2.3	2.2	1.0
San Joaquin	3.6	15.6	23.3	27.9	12.3	8.9	4.8
Santa Clara	0.0	3.7	22.0	58.0	5.1	4.8	7.0
Highest	5.1	21.4	30.5	60.0	24.1	11.3	7.0
Lowest	0.0	3.1	15.5	25.8	2.3	0.2	1.0
Average	1.5	12.7	23.6	37.8	12.6	7.6	3.7

The sand soils in the arid regions are as rich as the other soils, and when irrigated are recognized as one of the most important soil types of the west. They are leachy if the soil grain is large. The finer the sand the more valuable the soil as a rule. They are quickly parched in dry weather, absorbing little if any moisture from the air. They dry out quickly after rain, or irrigation, and can be worked quickly. They are warm and hold heat well, and are best adapted to quick growing crops. Soils that contain less than twenty per cent of silt and clay are called sand, if they contain more than twenty-five per cent of fine gravel and medium sand, and less than fifty per cent of fine sand. They vary from fine to medium texture, and are generally micaceous and smooth. Light, open, loose, or only slightly coherent, they are very porous and friable. They are not retentive of moisture, generally well drained and are easily culutivated, as they never clod or bake, and there is no danger of puddling.

FRESNO SAND. Mapped in the Fresno, Hanford, Madera, Modesto-Turlock, and Stockton areas. That mapped as Fresno sand in the Bakersfield, Sacramento, San Bernardino, San Gabriel, and Santa Ana

areas has been reclassified as Hanford sand. That mapped as Fresno sand in the Indio area has been reclassified as Indio sand. White, gray, brown, six feet. SUBSOIL: White sandy loam. OCCURS: In strips, on uniform sloping plains, in dune-like ridges. ORIGIN: From the "White formation," consisting of interstratified sands, sandy loams, and volcanic ash deposits. CROPS: Wherever well drained, peaches, grapes, almonds, nectarines, apricots, cherries, olives, alfalfa, sweet potatoes, cantaloupes, berries, early truck. Free from harmful quantities of alkali, and when well drained none need rise from the subsoil.

HANFORD SAND. Mapped in the Portersville area. Mapped as Fresno sand in the Bakersfield, Los Angeles, Lower Salinas Valley, Sacramento, San Bernardino, San Gabriel, and Santa Ana areas. Light gray to brown, slightly yellowish, medium to coarse, four to twenty feet. SUBSOIL: Sand, gravel, local hardpan. OCCURS: On lower terraces, level plains, gentle slopes, lower edge of mountain aprons, along streams, in slightly depressed areas representing former streams, in strips, smooth, level, locally slightly wind-blown. ORIGIN: Recent sedimentary deposits, from original granitic material, deposited by shifting currents and flood waters of adjacent and former streams. CROPS: Adapted to any crop suited to the local climatic conditions; to fruits that require well drained soils that can be irrigated during the dry season. Planted to truck crops, grains, alfalfa, deciduous fruits, raisin grapes, potatoes in the north, wine grapes, peaches, citrons, apricots, in the south; the walnut groves of Rivera, Anaheim, Fullerton, Elmonte and Santa Ana; the oranges and lemons of Covina, and Santa Ana; celery of Santa Ana, etc. Generally free from alkali, a few spots the exception.

IMPERIAL SAND. Mapped in the Imperial area. Mapped as Gila fine sand, Yuma area. Fine to coarse, organic matter small per cent. SUBSOIL: Loam, clay loam, sandy clay, clay. OCCURS: Smooth, level, near sandunes. ORIGIN: Same material as sandunes. CROPS: One of the best soils in Imperial Valley, suitable for any crops adapted to the climate. Practically free from alkali except where underlaid by heavy subsoil.

INDIO SAND. Mapped as Fresno sand in the Indio area. Whitish gray, six feet. SUBSOIL: Same but coarser. OCCURS: Skirting the mountains, above present water supply. ORIGIN: Old beach sand with material washed down from the mountain. CROPS: Would make good soil for fruits, grains and alfalfa. Free from alkali. Not analyzed. GRAVELLY PHASE: Grayish white, coarse hard material, six feet or more, above the old beach line, alluvial fans and cone deltas, caused by storm waters.

MADERA SAND. Mapped in the Madera area. Brown, three to six feet. SUBSOIL: Red hardpan. OCCURS in long narrow bodies parallel to shallow water courses on rolling land, marked by hog-wallows. ORIGIN: Doubtful—possibly from blowing out of material from dry stream courses. CROP: Grain; adapted to alfalfa, grapes, figs, olives, stone fruits.

MARICOPA SAND. Mapped as Fresno sand, gravelly phase, in the Ventura area. Light brown to white, gravelly, six feet. SUBSOIL: Variable. OCCURS: As long, gentle sloping valleys, floor of small

washes, next terrace above bottom lands, smooth to steep sloping. ORIGIN: Coarsest wash from the hills, by small streams and heavy downpours. CROPS: Fruits suited to the climate, lima beans. Free from alkali.

OAKDALE SAND. Mapped in the Modesto-Turlock area. Light brown, micaceous, carries silt and clay, six feet. SUBSOIL: Same, heavier. OCCURS: Along the lower slopes of terraces, smooth, gently sloping. ORIGIN: Working over of the Oakdale coarse sandy loam by the wind, the finer particles collecting along the lower sides of the terraces. CROPS: Almonds; adapted to many crops where irrigated.

OXNARD SAND. Mapped in the Los Angeles, San Bernardino and Ventura areas. Gray to yellowish gray, dark gray, gray brown; may grade into indurated sand; number of local phases; six to ten feet. SUBSOIL: Same. OCCURS: At the edge of mesas, rolling, undulating, in ridges or as dunes, wind-blown, in hills, on deltas. ORIGIN: Blown out of the adjacent soils, largely aeolian, beach sand driven inland. CROPS: Olives, grains, corn, barley, peas, sugar beets, grapes, citrus fruits, berries, truck, flowers. Free from alkali.

PAJARO SAND. Mapped in the Pajaro area. Light brown, six feet. SUBSOIL: Same, heavier. OCCURS: At the junction of streams by a rapid rush of large bodies of water. ORIGIN: Alluvial and sedimentary. CROPS: Fruits, vegetables and grains, when not too wet Not analyzed.

SACRAMENTO SAND. Mapped in the Red Bluff and Woodland areas. Light to dark gray, two to four feet. SUBSOIL: Sand heavier texture. OCCURS: Ridges and mounds subject to overflow. ORIGIN: Wash from the rivers deposited by rapidly moving waters. CROPS: Requires leveling, and protection from floods before using for truck crops.

SAN JOAQUIN SAND. Mapped as Fresno sand in the Fresno area. Mapped as Fresno red sand, Sacramento area. Gray to dark brown, six feet. SUBSOIL: Red sandy loam, red sandy adobe, red sandy hardpan. OCCURS in irregular shaped bodies, summits of higher ridges, undulations and upper valley margins. ORIGIN: From adjacent granitic rocks, intermingled with the wash from diabase, amphibolite and volcanic rocks, ancient Pleistocene lake deposits, weathering of red sandstone formation. CROPS: One of the most important soils of the Sacramento area; citrus and stone fruits, figs, peaches, plums, prunes, cherries, apricots, olives, nectarines, raisin grapes. Alkali not present in harmful quantities.

SANTA CRUZ SAND. Mapped in the Pajaro area. Light to dark red, reddish brown, three to six feet. SUBSOIL: Disintegrated red sandstone. OCCURS: Occupies spurs of the mountains. ORIGIN: Weathering of red sandstone in place. CROPS: Oats and Indian corn, eucalyptus trees.

DUNESAND. Mapped in the Indio, Imperial, Los Angeles, Pajaro, and Ventura areas. Also called coastal sand, beach sand, etc. The name "dune" is given to the rounded hills and ridges of wind-blown sand common in arid regions and along windy shores. They are nat-

urally of moderately fine and uniformly assorted materials as shown by an analysis: Fine gravel 0.0, coarse sand 24.7, medium sand 46.3, fine sand 25.2, very fine sand 0.8, silt 1.7, and clay 1.6. They are usually considered undesirable for agricultural purposes, but they are not infertile in the sense that they lack the mineral elements of plant food, as they contain the ordinary soil minerals and wherever reclaimed have proven perfectly capable of supporting agriculturally valuable vegetation. The barrenness of the dunesand is due to lack of water and instability of surface rather than to any deficiency of mineral plant nutrients. Although very absorptive, these sands have very little power to retain moisture, and it is generally too expensive to level them for irrigating. They are free from alkali or contain only harmless amounts. They are well drained and have a texture favorable for cultivation. Many of the choice orchards of Southern California were considered a couple of decades ago as worthless sandhills, and now serve to show what many so-called dune wastes could become if properly handled. The first step is stopping the sand movement and establishing a stable and permanent surface. This is done by planting grasses which will bind the surface and protect it from attack by the wind. Marram or beach grass (Ammophila areparia) has been found particularly useful on coastal dunes. Many reclaimed areas are then put into forest. The reclamation work at Golden Gate Park, San Francisco, shows what may be accomplished with these sands.

RIVERWASH AND ROCK OUTCROP. Mapped in the Colusa, Red Bluff, Redding, Livermore, San Bernardino, Bakersfield, Modesto-Turlock, Madera, Sacramento, Los Angeles, Portersville, San Jose, San Gabriel, Ventura, Lower Salinas Valley, Fresno, and Woodland areas. SOIL: Consists of a mixture of rounded and flattened gravel, cobblestones, sand and finer sediments, the coarser material greatly predominating, merges into adjacent fine sands and gravelly loams, leachy character, six inches to six feet. OCCURS: Occupies beds of portions of the flood plains, lower terraces, abandoned and present creek and river channels, subject to overflow, low flat sandbars and spits. ORIGIN: Recent alluvial, from a great variety of rocks. CROPS: Generally barren and of no value except for grazing.

ROUGH STONY LAND. Mapped in the Colusa, Redding, Portersville, Sacramento and Yuma-California areas. SOIL: Light red, gray, drab, yellow red, loam or clay loam, friable, carries relatively large amount of cobbles, small boulders and gravel, six inches to six feet, from bare rock outcrops to sand. SUBSOIL: Yellow, red, clays, indurated clay hardpan, volcanic ash, breccias. OCCURS: In narrow elongated bodies, bordering stream valleys, higher hilly portions or knolls of uplands, rugged hills. ORIGIN: From ancient alluvial deposits, from volcanic muds and breccias, residues. CROPS: Grazing.

PEAT. Mapped in the Los Angeles, San Bernardino, Santa Ana and Stockton areas. Dark brown to black; smooth, pasty consistency when wet, depth variable, no tendency to puddle, friable, easily cultivated when once broken, light weight, poorly drained. SUBSOIL: Sand, silts, or sandy clay. OCCUR at river deltas, shallow fresh water lakes, former lake beds, near springs. ORIGIN: Formed by the decay of

vegetation in shallow lakes, ponds, or swamps; some clay and silt are blown in by the winds or carried in by streams; they contain from thirty to ninety per cent of humus; from aquatic plants in various stages of decomposition, fine alluvial river or tidal silt intimately mixed with partially decayed vegetation, plant roots, stems, and fibres in great profusion, or vegetable matter grown and more or less preserved in standing water, growing and decaying tules. CROPS: If the vegetable matter is sufficiently decayed and mingled with some minertl matter, and the soil is well drained, they yield enormously under favorable conditions, but successive croppings decrease production. Asparagus, beans, celery, onions, timothy, redtop, rye grass, clover, grains, corn, potatoes. Naturally free from alkali.

MUCK. Muck soils represent the advanced state of change in peat areas. They are of limited extent and poorly drained. They are highly valued for their adaptation to special crops, such as celery, onions, peppermint, etc.

LAKE AND MARSH SOILS. Mapped in the Butte Lake area. Formed in shallow lakes such as favor the growth of aquatic plants, as the tules (Scirpus) and cat-tails (Typha) which form great masses of decaying matter, giving to the loamy and sandy soils a friable mucky or peaty character. When properly drained they are extremely fertile and produce immense crops of timothy, clover, red top, potatoes, celery, asparagus, etc.

MEADOW SOIL. Mapped in the Fresno area. Fine gravel 0.0, coarse sand 0.3, medium sand 1.9, fine sand 10.1, very fine sand 45.9, silt 31.5, clay 5.3. These soils consist mainly of very fine sand and silt with a little clay. They are fine micaceous sandy loams with little true clayey matter, and very little coarse sand or gravel, variable in texture, color and depth. OCCUR: They comprise lowlying, flat, and poorly drained land of variable texture, on the "Meadows" along Kings River, along river bottoms. ORIGIN: Sediments dropped by rivers in flood, in part material cut from the banks, sorted over, and laid down. CROPS: Much of it can be reclaimed by draining, and it is then adapted to a variety of crops, pasture, truck, orchards, corn. Alkali is occasionally found in a few spots.

CHAPTER XXI

HARDPAN. ALKALI.

Hardpan in the true sense of the word is not bedrock, nor a material formed under the water as sedimentary rocks are formed, but is a secondary product formed in the soil through local conditions. All water which percolates through the soil soon dissolves from it soluble materials of different kinds. A change of temperature, a checking of the water movement, or a rapid loss of the contained gases, or other causes may precipitate hardpan near the zone of change. It is impenetrable to plant roots and limits the root zone of crops; cultivation is interrupted, movement of the soil water is arrested, drainage retarded, and the power to retain and to deliver water is decreased. Hardpan is subject to much variation, even in short distances. It may be exposed on the surface where the soil has been subject to erosion, or it may occur at any depth below the surface. Where it is thin, easily disintegrated, low in alkali contents, and easily penetrated by plant roots, it is not harmful and may even be beneficial in holding the moisture within reach of the plants.

Where it occurs near the surface or where it is very hard it is harmful in several ways. It prevents the deep penetration necessary for trees, vines and alfalfa. It restricts drainage, often forming shallow basins of water-saturated soil fatal to plant roots. The excess of lime occurring in hardpan is especially injurious to citrus fruits, as indicated by the yellowing of the leaves. Indications of hardpan are usually seen in hummocky, uneven surface, and small shallow depressions, the result of deficient drainage. When the hardpan is three or four feet below the surface the land may be adapted to vines and other shallow rooted growths. Trees require deep soils and hardpan must be broken up by blasting where the trees are to be planted.

ALKALI SOILS

Lands may carry alkali salts in sufficient quantities to become more or less a menace to irrigated crops. These salts are sodium chloride, magnesium chloride, calcium chloride, sodium sulfate, magnesium sulfate, calcium sulfate, and sodium carbonate. When sodium carbonate is present, the salt mixture is commonly known as "black alkali," because the charring effect of this salt upon organic matter gives a characteristic black color to the soil. When sodium carbonate is absent, the salts effloresce on the surface as a white powder, or crust, called "white alkali." The white alkali is not so injurious to crops, and is much more soluble than the black alkali. The greater part of the alkalies originate from alkali-bearing shales and other sedimentary rocks, especially from those of marine origin. Alkali is confined chiefly to the heavier soil types, and normally is more apt to be distributed through the subsoils. There is no evidence that there are deep seated accumulations of alkali.

CLASSIFICATION OF ALKALI SOILS. The percent of alkali in the soils is determined in the field when the soil maps are made by means of the electric resistance of the soil solution, each foot section being determined separately, and are also determined volumetrically in the field from the total of soluble salts.

The alkali contents of the soils are graded according to the average salt contents to the depth of six feet, as follows:

No. 1	0. to 0.20 per cent
" 2	0.20 to 0.40 per cent
" 3	0.40 to 0.60 per cent
" 4	0.60 to 1.00 per cent
" 5	1.00 to 3.00 per cent

LIMITS OF ENDURANCE. A number of factors enter into the limit of endurance of plants for alkali. With the same amount of alkali, plants will suffer less in heavier soils than in sandy. Crops will stand more alkali with thorough cultivation, and they will stand a considerable amount of alkali if they are started under favorable conditions. In some districts sugar beets do well on soils containing a large amount of alkali. They are planted when the ground is wet by rains, or irrigation, which carries the alkali into the depths of the soil. When the soil dries out the alkali is brought to the surface and is left above the area of the active roots. Where the average alkali content is less than 0.20 per cent, no injury to crops may be feared under general conditions. This is, however, considered the minimum limit of danger for ordinary irrigated crops. Many crops can be successfully grown where the average concentration is from 0.20 to 0.40 per cent, but lands ranging from 0.40 to 0.60 per cent are generally devoted to pasture. Over 0.40 by no means takes away the value of the land for some agricultural purposes. Some of the hardier fruits, especially pears, can be grown under intelligent cultivation. Onions, asparagus, and sugar beets, barley, grain or hay, will resist this per cent if the ground is well prepared for the seed bed and the salts kept away from the tender young roots by frequent irrigation and cultivation. Sorghum, sugar beets and alfalfa have produced partial to full crops on land ranging from 0.40 to 0.60. With black alkali, 0.05 is the minimum of concentration beyond which crops begin to suffer.

Some alkali salts are readily carried into solution and their distribution in the soil is determined largely by the movements of soil waters. The concentration in lower valley plains and depressions of deficient drainage has been caused mainly by evaporation from flood waters charged with small quantities of alkali salts leached from the higher adjacent soil bodies and from alkali-bearing rocks. Rapid evaporation, long periods of hot dry weather, compact, uncultivated and unshaded soil surfaces, with water table near the surface tend towards concentration of alkali at or near the surface. While the concentration and distribution of alkali in the soil and subsoil depends upon a variety of circumstances, it will be found that the main ones are—soil texture and structure, position of the underground water table, and the rapidity, direction and movement of the soil waters. Where soils are subject to overflow and have a high water table there is an accumulation of salts at the intervals between floods. Each over-

flow washes the salts out and leaves the soil temporarily free from the salts at the surface. These lands are called "intermittent alkali lands." The alkali salts are readily dissolved and carried downward and outward in soils of loose, open texture and structure, by water applied in excess of saturation. In soils of fine texture and compact structure the salts tend to cling to the finer particles, checking the downward movement, hence salts tend to collect near the surface and within the root zone of crops. Heavy rains, as well as surface irrigation, soaking downward into the soil dissolve and carry the salts downward by gravity to the limits of penetration. If the surface flooding be copious and gravitation movement aided by natural or artificial underdrainage, large amounts of the alkali may be permanently removed. As soon as the downward movement of flood waters ceases, an upward movement begins through capillary action caused by the surface evaporation, causing a surface crust of alkali as the waters evaporate. The surface should be kept, between the periods of flooding, in a condition of fine tilth by cultivation, the mulch of loose earth retarding evaporation and the upward movement by capillarity. As soon as the soil is free from excess, by underdrainage and occasional flooding, thorough cultivation should begin, using alkali-resisting crops which can be cultivated frequently or which shade the surface, as sorghum, sugar beets or alfalfa. In the case of black alkali, the application of gypsum to the surface is beneficial, changing the sodium carbonate into the more soluble sodium sulfate.

APPENDIX

CHANGED SOIL NAMES

The following list gives the soil names in published reports of the U. S. Bureau of Soils that as a result of correlation have been changed or dropped. In the first column is given the name at present used, in the second column is given the original name.

BAKERSFIELD AREA

Present Name	Name as published
Hanford sand	Fresno sand
Hanford fine sand	Fresno fine sand
Hanford fine sandy loam	Fresno fine sandy loam
Fresno loam	Maricopa loam
Placentia sandy adobe	Maricopa sandy adobe
Hanford clay loam	Oxnard silt loam
Placentia sandy loam	Placentia sandy loam
Riverwash	Riverwash
Gravelly areas	Gravelly areas

COLUSA AREA

(No changes in Colusa area yet.)

Norman clay adobe
Orland fine sandy loam.
Orland fine sand.
Riverwash.
Rough stony lands.
Sacramento gravelly sandy loam.
Sacramento fine sandy loam.
Sacramento loam.
Sacramento silt loam.
Sacramento silty clay loam.
Sacramento silty clay.
San Joaquin gravelly loam.
San Joaquin loam.
Sites sandy loam.
Sites loam.
Sites clay loam adobe.
Willows loam.
Willows silty clay loam.
Willows clay loam.
Willows clay.
Willows clay adobe.

FRESNO AREA

Stockton fine sandy loam	Fancher sandy loam
San Joaquin sand	Fresno red sand
Fresno fine sandy loam	Fresno sandy loam
San Joaquin sandy loam	San Joaquin red adobe
San Joaquin sandy loam	San Joaquin sandy loam
Stockton clay loam adobe	San Joaquin black adobe
Placentia clay loam adobe	Sierra adobe
Riverwash	Riverwash
Meadow	Meadow

Present Name	Name as published
HANFORD AREA	
Hanford sandy loam	Fancher sandy loam
Fresno sand	Fresno sand
Fresno sandy loam	Fresno sandy loam
Hanford fine sand	Hanford fine sand
Hanford fine sandy loam	Hanford fine sandy loam
Stockton clay loam adobe	San Joaquin black adobe
IMPERIAL AREA	
Gila fina sandy loam	Gila fine sandy loam
Dunesand	Dunesand
Imperial sand	Imperial sand
Imperial sandy loam	Imperial sandy loam
Gila loam	Imperial fine sandy loam
Indio gravelly loam	Imperial gravelly loam
Imperial clay loam	Imperial loam
Imperial clay	Imperial clay
Gila silt loam	Imperial silt loam
INDIO AREA	
Dunesand	Dunesand
Indio sand	Fresno sand
Indio fine sandy loam	Fresno fine sandy loam
Indio fine sand	Fresno sandy loam
Imperial clay	Imperial clay
LOS ANGELES AREA	
Hanford fine sand	Fresno fine sand
Hanford fine sandy loam	Fresno fine sandy loam
Placentia loam adobe	Fullerton sandy adobe
Hanford sand	Fresno sand
Galveston clay	Galveston clay
Placentia loam	Los Angeles sandy loam
Maricopa fine sandy loam	Maricopa gravelly loam
Maricopa sandy loam	Maricopa sandy loam
Oxnard sand	Oxnard sand
Oxnard clay loam	Oxnard loam
Peat	Peat
Placentia fine sandy loam	Placentia sandy loam
Hanford loam	Santiago silt loam
Hanford clay loam	Santiago silt loam
Oxnard clay loam adobe	San Joaquin black adobe
Sierra sandy adobe	Sierra adobe
Riverwash	Riverwash

REDDING AREA

(No changes in the Redding area.)

Anderson gravelly loam.
Anderson fine sandy loam.
Bellavista sandy loam.
Redding gravelly loam.
Redding loam.
Riverwash.
Rough stony land.
Sacramento gravelly sandy loam.
Sacramento fine sandy loam.
Sacramento loam.
Sacramento silt loam.

SACRAMENTO AREA

Present Name	Name as published
Hanford sand	Fresno sand
Hanford fine sandy loam	Fresno fine sand
Hanford gravel	Fresno gravel
San Joaquin sand	Fresno red sand
Riverwash	Riverwash
Rock outcrop	Rock outcrop
Rough stony land	Rough stony land

Present Name	Name as published
Hanford silt loam	Sacramento silt loam
Hanford clay adobe	Salinas gray adobe
San Joaquin sandy loam	San Joaquin sandy loam
San Joaquin fine sandy loam	San Joaquin fine sandy loam
San Joaquin clay loam adobe	San Joaquin red adobe
Sheridan sandy loam	Sheridan sandy loam
Sierra stony loam	Sierra stony loam
Sierra sandy loam	Sierra sandy loam
Sierra loam adobe	Sierra loam
Sierra clay loam	Sierra clay loam

SALINAS AREA

Maricopa gravelly loam	Arroyo seco sandy loam
Hanford fine sandy loam	Fresno fine sandy loam
Hanford sand	Fresno sand
Hanford fine sand	Hanford fine sand
Placentia fine sandy loam	Placentia sandy loam
Riverwash	Riverwash
Salinas gray adobe	Salinas gray adobe
Oxnard gravelly loam	Salinas shale loam
Hanford silt loam	Santiago silt loam
Hanford clay loam	Santiago silt loam
Oxnard clay loam adobe	San Joaquin black adobe
Maricopa gravelly sand	Soledad gravelly sand

SAN BERNARDINO AREA

Hanford fine sandy loam	Fresno fine sandy loam
Placentia sandy adobe	Fullerton sandy adobe
Hanford sand	Fresno sand
Maricopa gravelly sand	Maricopa gravelly sand
Maricopa loam	Maricopa sandy loam
Oxnard sand	Oxnard sand
Oxnard sandy loam	Oxnard sandy loam
Oxnard fine sandy loam	Oxnard fine sandy loam
Oxnard loam	Oxnard loam
Peat	Peat
Placentia fine sandy loam	Placentia sandy loam
Placentia clay loam	Placentia loam
Placentia coarse sandy loam	Placentia coarse sandy loam
Riverwash	Riverwash
Salinas gray adobe	Salinas gray adobe
Hanford clay loam	Santiago silt loam
Maricopa sandy loam	San Gabriel sandy loam
Maricopa gravelly loam	San Gabriel gravelly loam
Maricopa gravelly sand	San Gabriel gravelly sand
Oxnard clay loam adobe	San Joaquin black adobe

SAN GABRIEL AREA

Hanford sand	Fresno sand
Hanford fine sandy loam	Fresno fine sandy loam
Placentia fine sandy loam	Placentia sandy loam
Riverwash	Riverwash
Hanford clay loam	Santiago silt loam
Maricopa gravelly loam	San Gabriel gravelly loam
San Gabriel gravelly sand	San Gabriel gravelly sand
Oxnard clay loam adobe	San Joaquin black adobe

SAN JOSE AREA

Maricopa gravelly loam	Arroyo Seco sandy loam
Hanford silt loam	Fresno fine sandy loam
Galveston clay	Galveston clay
Oxnard clay loam	Oxnard loam
Oxnard silt loam	Oxnard silt loam
Placentia fine sandy loam	Placentia sandy loam
Riverwash	Riverwash
Salinas gray adobe	Salinas gray adobe
Stockton clay loam adobe	San Joaquin black adobe

Present Name	Name as published
SANTA ANA AREA	
Hanford sand	Fresno sand
Hanford fine sandy loam	Fresno fine sandy loam
Palcentia loam adobe	Fullerton sandy adobe
Peat	Peat
Placentia fine sandy loam	Placentia sandy loam
Oxnard clay loam adobe	San Joaquin black adobe
Santiago fine sandy loam	Santiago sandy loam
Santiago loam	Santiago loam
Hanford clay loam	Santiago silt loam
SOLEDAD AREA	
Placentia sandy loam	Placentia sandy loam
Fresno sand	Fresno sand
Maricopa gravelly sand	Soledad gravelly sand
Maricopa gravelly loam	Arroyo Seco sandy loam
Oxnard gravelly loam	Salinas shale loam
Salinas gray adobe	Salinas gray adobe
Riverwash	Riverwash
Hanford fine sand	Hanford fine sand
Fresno fine sandy loam	Fresno fine sandy loam
Hanford clay loam	Santiago silt loam
STOCKTON AREA	
Stockton fine sandy loam	Fancher sandy loam
Fresno sand	Fresno sand
Fresno fine sand	Fresno fine sand
Fresno sandy loam	Fresno sandy loam
Fresno fine sandy loam	Fresno fine sandy loam
Peat	Peat
Sacramento clay loam	Sacramento clay loam
San Joaquin sandy loam	San Joaquin sandy loam
San Joaquin loam	San Joaquin loam
Stockton loam	Stockton loam
Stockton loam adobe	Stockton loam adobe
Stockton silt loam	Stockton silt loam
Stockton clay loam adobe	Stockton clay loam adobe
Stockton clay adobe	Stockton clay adobe
VENTURA AREA	
Dunesand	Dunesand
Maricopa sand	Fresno sand (gravelly phase)
Oxnard loam	Fresno fine sandy loam
Placentia sandy adobe	Fullerton sandy adobe
Oxnard sand	Oxnard sand
Oxnard sandy loam	Oxnard sandy loam
Oxnard clay loam	Oxnard loam
Oxnard silt loam	Oxnard silt loam
Placentia loam	Placentia sandy loam
Riverwash	Riverwash
Oxnard gravelly loam	Salinas shale loam
Oxnard clay loam adobe	San Joaquin black adobe
Maricopa gravelly loam	San Gabriel gravelly loam
YUMA-CALIFORNIA AREA	
Maricopa sand	Fresno gravelly sand
Gila fine sandy loam	Imperial sandy loam
Gila loam	Imperial fine sandy loam
Gila silt loam	Santiago silt loam in 1902 map: changed to Imperial silt loam 1904.
Gila clay loam	Imperial loam
Rough stony land	Rough stony land
Imperial sand	Imperial sand

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